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DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON THE

CURRENT OPERATIONS AND FUTURE MISSION OF THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

JULY 25, 1990

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DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

WEDNESDAY, JULY 25, 1990

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 10 a.m. in room SD-366, Dirksen Senate Office Building, Hon. J. Bennett Johnston, chairman, presiding.

The CHAIRMAN. Ladies and gentlemen, before we begin the hearing this morning I would like to take note of talents of our first witness which are not generally known around the country. Our first witness is a noted musician who, when he came to Louisiana, was able to exhibit those great talents to people in Lafayette, Louisiana. It was a working trip, but he was able to instruct us all in the operation of the washboard, which is a great musical instrument used in Cajun bands.

Senator FORD. Did he learn that at an early age?

The CHAIRMAN. He is a quick learner.

So Mr. Secretary, I have the washboard that you played on——

[Laughter.]

The CHAIRMAN [continuing]. And a picture of you with your assistant.

[Laughter.]

The CHAIRMAN. You may demonstrate if you like.

[Applause.]

Secretary WATKINS. I would like to tell the Chairman and the Committee members that I took the Rorschach test when I was at Oak Ridge National Laboratory for my master's degree in nuclear engineering and mechanical engineering, and they said I should not be there, that I should have been a drummer. I took it again, and it came out drummer again. So I think you saw some real hidden talents there, Mr. Chairman, in your trip. I was delighted to have the little presentation this morning but was a little disappointed that you did not give me the picture of both you and I on the washboard together. It is the same event.

The CHAIRMAN. That is.

Secretary WATKINS. Oh, good. That is wonderful.

Senator BURNS. I would say to the Chairman on the presentation of the washboard, it looks a little bit different than we use up in Montana. I want to know where they keep their soap.

[Laughter.]

The CHAIRMAN. We do not use soap.

[Laughter.]

OPENING STATEMENT OF HON. J. BENNETT JOHNSTON, U.S. SENATOR FROM LOUISIANA

The CHAIRMAN. With that, this meeting will come to order.

Today the subcommittee will receive testimony on the future role and mission of the Department of Energy's national laboratories. I congratulate Senator Ford, the Chairman of the Subcommittee on Energy Research and Development for scheduling this hearing.

The national laboratories are an extremely important piece of the Department of Energy. Over the years, the national laboratories have made a significant contribution to our understanding of science and to our technological capability. From the earliest days of the Manhattan Project, the labs have been a tremendous resource for basic and applied research, fundamental science, and development of technology. It is essential that we continue to use these labs to their fullest potential.

Today's hearing is very timely. The laboratories are on the brink of major changes in the way they operate. The past emphasis on weapons research and development is no longer appropriate. As there is less need for defense capability at the labs, there will be less defense dollars to support them.

So it is important and very timely to examine the future role and mission of the national laboratories. The research and development programs undertaken by the labs cover the full spectrum of the fundamental sciences. Many of these programs should be enhanced and expanded. Others can probably be scaled back. In all cases, our research and development programs need better coordination among the labs and with industry and the academic community. Where possible, we need to better facilitate the transfer of technology to the private sector.

I look forward to hearing today from Admiral Watkins. He has faced head on the challenge of the future mission of the national laboratories. Admiral Watkins has already proposed a number of initiatives to utilize better the expertise and resources of the national laboratories.

We will also hear today from the directors of the six national laboratories. They can tell us first-hand about the challenges faced by the laboratories and about their ideas for the future.

It is a vital subject, and before we hear from Admiral Watkins I would like to ask Senator McClure if he has any comments.

STATEMENT OF HON. JAMES A. McCLURE, U.S. SENATOR FROM IDAHO

Senator MCCLURE. I would just place my statement in the record, Mr. Chairman.

[The prepared statement of Senator McClure follows:]

PREPARED STATEMENT OF HON. JAMES A. MCCLURE, U.S. SENATOR FROM IDAHO

FUTURE ROLE OF DOE NATIONAL LABORATORIES

Over the years DOE's national laboratories have developed an internationally recognized expertise than can contribute to our quest for solutions to many pressing national and world problems. Because of this multi-disciplinary capability, Dixy Lee Ray, in her December 1973 Report to President Nixon on the Nation's Energy Future, recommended establishment of what became the Energy Research and Development Administration.

The former AEC national laboratories thus became the cornerstone of the efforts by the Nixon Administration and the Congress that eventually led to establishment of multi-disciplinary research capabilities that now reside in the Department of Energy.

Even then, in 1973, certain of DOE's laboratories were internationally recognized for their expertise in the basic and applied sciences—an expertise that has served us well in many research and development areas. One of the building blocks was the engineering capabilities that still reside at INEL (the Idaho National Engineering Laboratory) which, I observe, is not represented here today.

We have learned much in the intervening years, and have made our share of mistakes in efforts to develop and commercialize new energy technologies. What is now needed is greater emphasis on collaboration and partnership with industry and universities to advance America's demonstrated research capabilities into commercially available technologies.

Secretary Watkins is to be commended in his efforts to place greater emphasis on improving our nation's competitive posture and to promoting science and engineering education. This effort builds on the foundation laid by this Committee and the Congress in the early 1970's and recently reflected in the National Competitiveness Technology Transfer Act (the 1989 amendments to the Stevenson-Wydler Technology Innovation Act of 1980) and the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989.

More recent initiatives by this Committee include the National Energy Policy Act of 1990 (S. 324). In addition, Senator Domenici recently introduced the Department of Energy Science and Education Enhancement Act (S. 2856), which is currently pending before this Committee.

The significant challenges of the 90's form a mosaic of multi-disciplinary issues. Demonstrating simultaneous concern for environmental values, energy security and economic competitiveness is a prerequisite for public acceptance of new technologies. Some of DOE's national laboratories can play a critical role in solving many of today's energy and environmental problems.

However, I have two basic concerns: First, the research and development capabilities that exit at DOE's national laboratories were initially established by the Federal government for its use in the achievement of specific defense objectives and more recently, to achieve certain energy and environmental policy objectives that are viewed to be in the national interest. Our nation would be will served if these facilities were to either substitute for private sector research and development activities or enter into competition with the private sector in the commercialization of new energy or environmental technologies.

Second, some DOE laboratories were established to meet specific defense needs, for example, at Rocky Flats and Savannah River. In such instances, the overall national interest might best be served if certain DOE facilities with defense related missions remained so, even where there exists an expertise that has private sector application. In making this observation I recognize that DOE is a leader in energy and science and in national security.

In this regard, I look forward to hearing from Secretary Watkins as to what he has in mind for the future role of DOE's national laboratories.

The CHAIRMAN. Senator Ford.

STATEMENT OF HON. WENDELL H. FORD, U.S. SENATOR FROM KENTUCKY

Senator FORD. Mr. Chairman, I will place my statement in the record.

I want to thank you for pushing us to have this meeting today. I want to read just one part of the statement I entered for the record.

There are important programs in basic research and civilian energy research and development at the labs. We are engaged in work at the labs that is on the leading edge of science. In my opinion, we are developing technology that can drastically change the way we do business.

Several weeks ago, Senator Domenici and I in this Subcommittee heard about significant developments in the human genome project. There are many other important civilian research programs at the labs, and I am afraid these projects have been overshadowed by the weapons programs for far too long. Perhaps as we move into the post-Cold War era we will put the proper emphasis back on civilian research.

What I am looking for today in the testimony, Mr. Chairman, are answers to these questions.

Is the existing lab structure outdated?

Should we restructure the lab system to better coordinate research and development among the labs?

Should each of the labs serve a single purpose?

Should individual projects have a lead laboratory or center of excellence?

Do we need as many labs as we have, or maybe we need more?

Can we justify Federal spending for all the lab programs, or do we need to look for new sources of funding?

I think there is approximately 50,000 employees associated with the labs. That is roughly a little less than 10,000 per lab. That is a lot of people, and I am not sure how many you would consider to be doing research and how many would be support employees. Nevertheless, we will get into that later.

I do again thank the Chairman for his effort here this morning, and I look forward to the hearing.

[The prepared statement of Senator Ford follows:]

PREPARED STATEMENT OF HON. WENDELL H. FORD, U.S. SENATOR FROM KENTUCKY

Good morning. The purpose of today's hearing is to receive testimony on the future role and mission of the Department of Energy's national laboratories. I thank the Chairman of the full Committee, Senator Johnston, for encouraging us to hold this hearing.

The national laboratories have played an important role in energy research and development in this country. The labs have been a significant source of advanced technology. They have contributed greatly to our scientific capability. Without question, the labs are a national asset.

The laboratories are now at a crossroads. Many of the labs find their roots in the Manhattan Project of the 1940s. And as the weapons program grew over the next four decades, so did the laboratories. In many ways, the weapons program became the bread and butter of the labs. Funding for the laboratories now represents about 30 percent of the Department of Energy's total budget. We spend over $5 billion annually at the labs.

But times are changing. The world is changing, and the cold war is over. We do not need the same defense capability at the national labs. The labs are going to have to find a new mission. They may need to find new sources of funding.

To be sure, there are important programs in basic research and civilian energy R&D at the labs. We are engaged in work at the labs that is on the leading edge of science. We are developing technology that can drastically change the way we do business. Several weeks ago, this subcommittee heard about the significant developments in the human genome project.

There are many other important civilian research programs at the labs. I am afraid these projects have been overshadowed by the weapons program for too long. Perhaps as we move into the post-Cold War era, we will put the proper emphasis back on civilian research.

But we also must find the proper role for the national labs in the future. We need to decide on appropriate changes to the lab system that reflect the world changes.

—Is the existing lab structure outdated?

—Should we restructure the lab system to better coordinate R&D among labs?

—Should each of the labs serve a single purpose? Should individual projects have a lead laboratory or "center of excellence"?

—Do we need as many labs? Or do we need more?

—Can we justify federal spending for all of the lab programs? Do we need sources of funding?

I hope that the witnesses today will address these questions.

The CHAIRMAN. Thank you, Senator Ford.

Now I want to call on Senator Domenici, who has long been a leader and an innovator in this area, and who will continue to push not only in this committee, but in the Energy and Water Development Subcommittee of the Appropriations Committee.

Senator Domenici.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator DOMENICI. Thank you very much, Mr. Chairman.

Let me just say, because there is such interest here today and we have such distinguished witnesses, I will try very hard, although you know it is difficult, to be very unaccustomably brief.

Let me however say, I watched a documentary the other night about the Massachusetts Institute of Technology, Admiral, and the 4,000 scientists that were put together there to develop radar for the United States and the free world. Some people think it won the war. It was an amazing documentary, because as soon as the war was over, the documentary shifted to the goodbyes. And the greatest scientists in America were shaking hands as they shut it down. And they all went home. And they talked among themselves of this fantastic scientific experience of working together in this American-built laboratory to win that war.

Now I am not so sure that I could speculate on what might have happened had we not had them all shake hands and close it down. But I am absolutely certain that at these national laboratories that fate should not happen to them. As we look around the world and find that this is an era of science, with science changing exponentially, and enterprise capitalizing on it to grow and make new products, all of which is getting more complicated, I am absolutely certain that we will be making the biggest mistake in our economic history if we do not find a way to make the transition for utilization of this fantastic treasure found within the national laboratories.

So I believe this committee, Mr. Chairman, has a very rare opportunity in this decade to be a real power and a force in the development of science and technology for the private sector, with academia, through the proper use of these laboratories. It is a challenge, because we have to alter missions, we have to provide flexibility, and we have to have a Secretary who is strong enough to make sure that this flexibility that we give these laboratories and their directors is exercised in a prudent manner so that we can continue to get support.

There is no doubt, that within these laboratories is more expertise, more technological capability, more equipment to get on with new ideas and new science than anywhere else in the free world. And I for one am, on the one hand, exhilarated that it may focus on American economic, environmental, and educational problems; while on the other hand, I am very concerned because this committee should know that these laboratories were funded rather easily.

You know, Mr. Chairman, serving here and on the subcommittee, that nobody argued about funding, and everybody knows why. Because these laboratories were charged with maintaining peace. They were charged with maintaining our nuclear deterrent and one little mission under it: make sure we never get surprised in the nuclear armament area. A whopping challenge.

So who would worry about funding them?

We said to their leaders, the three directors of the nuclear labs and the others, you do that, and we will fund you.

Now we have this tremendous assemblage, and as the mission changes, this committee is going to have to be prudent enough to give them new assignments, and they have to be prudent enough to change their culture and their mission so that we can fund them. And I think that is the real test.

And, Mr. Secretary, I want to say one more time what I have said it on three occasions, but not here for a while—we who have confidence in America's science think that it is America's economic future. We think it is absolutely providential that at this time in history we have a Secretary that understands that role. And I believe you will tell us that today and you will share how you intend to do it.

Ultimately, these laboratories have to change their culture so they can serve the private sector and work with academia. As Sig Hecker once said, we have to make them user friendly. We think if you need new authority we ought to give it to you. But, essentially, I am very pleased with the attitude and the approach, but I am concerned that Congress might not understand it.

Thank you very much.

The Chairman. Thank you very much for an excellent statement, Senator Domenici.

Senator Bingaman.

STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

Senator Bingaman. Mr. Chairman, I have a statement I will just put in the record, and we will go ahead with the testimony. I do appreciate you holding the hearing. And I think it is a very important subject.

[The prepared statement of Senator Bingaman follows:]

Prepared Statement of Hon. Jeff Bingaman, U.S. Senator From New Mexico

I would like to thank Chairman Ford for holding this hearing to receive testimony from Secretary of Energy Watkins and the directors of the DoE national laboratories on the future of the labs. I believe that this is an important subject, and look forward to hearing the statements of Admiral Watkins and the laboratory directors.

The changes in the threat from Eastern Europe and the Soviet Union are continuing, and we are still in the early stages of adjusting to the new situation. Barring a radical reversal, it is clear that spending on nuclear weapons research and development will only decrease in the coming years. The need for safety upgrades on our present stockpile may keep the FY91 core weapons R&D budget at a level comparable to the FY90 level, but that funding will decline in the coming years, just as other defense funding will decline. This will have a significant impact on Lawrence Livermore, Los Alamos, and Sandia in particular.

I firmly believe that these laboratories are national treasures, and should be utilized to their fullest to help us meet the many challenges we continue to face. The scientific and engineering expertise of the laboratories can contribute much to economic competitiveness, through pre-competitive technology development, technology transfer, and manufacturing technology development and extension; to cleaning up our environment; to the math, science, and engineering education of our nation's youth; and of course in the areas of national security and energy where they have already contributed so much.

Be it good or bad, focusing on the national security implications of a problem has historically been the simplest way to get funding for the solution. The declining threat will make that very difficult in this case, and the on-going efforts to clean up the DoE production complex will make increased funding for the new missions of the labs even more difficult to come by. I feel very strongly that we should work to ensure that these laboratories do get funded in the coming year, and the DoE get the flexibility it needs to actively pursue initiatives in these areas.

I am looking forward to the results of the Secretary's Energy Advisory Board study of the future of the national laboratories, and I hope that Secretary Watkins will be able to address that study today. I am encouraged by Secretary Watkins commitment to develop a national energy policy, something I have long supported. I also strongly support the Secretary's on-going efforts in technology transfer and education, and commend the laboratory directors for moving out and embracing these initiatives in particular. I look forward to today's testimony on these issues, and expect that we will receive some useful insight into the issues surrounding the future of the labs.

The CHAIRMAN. Thank you very much.

Senator Murkowski.

STATEMENT OF HON. FRANK H. MURKOWSKI, U.S. SENATOR FROM ALASKA

Senator MURKOWSKI. Thank you, Mr. Chairman.

I welcome the Secretary and would like to renew an invitation for you to come visit Alaska. We hope that you can adjust your schedule. I remind you of the problems we have in trying to open up our frontiers to give our Nation some semblance of energy independence.

And I look forward to the Admiral proceeding with his testimony, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Admiral, welcome to the Committee.

Please proceed.

STATEMENT OF HON. JAMES D. WATKINS, SECRETARY, DEPARTMENT OF ENERGY

Secretary WATKINS. Thank you, Mr. Chairman.

I have submitted a formal statement, but I will have to say that it went through our normal clearance labyrinth and is as old as 5 days. In that 5 days I prepared an oral statement which I would also like submitted for the record, and I am going to abbreviate it a bit. I had hoped that copies of this would be in front of you now, but we will have them shortly. I would ask that perhaps you would allow the written oral statement that I am going to give to you in abbreviated form to be entered fully in the record.

The CHAIRMAN. Without objection, that will be done.

Secretary WATKINS. Thank you, sir.

I am very pleased to be invited here to testify. I think this is one of the most important issues on which I have testified on behalf of the Department of Energy this year, in fact, since I have taken over as Secretary.

I firmly believe that we stand on the threshold of an unparalleled decade of advances in research and education in the 1990's. The Department of Energy's national laboratories have a vital role to play in achieving the promise of the 1990's, in securing a future marked by peace through a strong and effective defense, and prosperity through affordable and environmentally benign energy technologies.

Our developing National Energy Strategy is documenting the tremendous need for improvements in energy technology across the board for every energy supply option, to improve energy efficiency, and to protect and improve our environment. It is my hope that the development of the National Energy Strategy will lead to a searching reevaluation of DOE's traditional research missions and activities, as well as a Department-wide R&D strategy that will allow DOE to take an integrated approach to spurring the development of the energy technologies that we will need in the next century.

The DOE laboratories will play a crucial role in the development of these technologies. As I discuss these national laboratories with you today, I will refer to all of the Department's laboratories when speaking about topics such as education and technology transfer. When I speak of the laboratories with missions in national defense, I will be speaking more specifically about three of the national laboratories whose directors are here with me today, that are responsible for nuclear weapons programs: Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories.

The Idaho National Engineering Laboratory is also an important contributor to national defense; the Director is not with us today.

The subcommittee should be aware, though, that even these three laboratories have substantial programs in non-nuclear weapons technologies, equaling about half of their overall research programs, and that they are already making important contributions to the development of energy technology.

I think it is very unfortunate that there are many in the private sector who feel that these are bomb factories. We have gone from 90 percent of our emphasis at Sandia, for example, in nuclear weapons research, development, testing, and production, to 50 percent in nuclear weapons areas. And this gives you an idea of the transition that has already taken place in just 20 years.

So we are already on the very steep slope of transitioning these laboratories to even more non-nuclear weapons programs and activities. And I think it is very important that everyone understands that. Because their contribution to areas of health and the well being of our society are significant. I think too often we look at programs, such as SDI, as being only related to a certain form of national defense, when in fact the technologies there all transfer to the private sector already, and are vital for so many other civilian activities in our society.

These are the kinds of things that I do not think get well aired, and so I applaud this hearing today to let our people speak about these kinds of things.

About defense missions. In the world of the 1990's, the need for a strong defense technology base will remain, even though the priorities among research areas related to nuclear weapons will shift. The new priorities will include continued enhancement of safety, security, survivability, and command and control of nuclear weapons. The manufacture of warheads will be increasingly dominated by issues of waste minimization in up-front design, waste management in downstream materials processing, and other environmental impacts.

Negotiated cuts in worldwide stockpiles of nuclear weapons will set the overall tone for defense decision-making in the United States. To preserve our national security and enhance global stability, the competencies at our nuclear weapons laboratories will become even more important than before. As the size of the stockpile decreases, considerations such as weapons reliability and safety, will loom larger. Maintenance of a competent cadre of nuclear weapons experts is essential if the United States is to have confidence in a nuclear deterrent that will remain a key part of its defense strategy, albeit reduced in size and scope, for years to come.

Along with expertise in nuclear weapons design and manufacture, the 1990's will require related expertise that currently is centered at the DOE national defense laboratories. These laboratories are the Nation's prime technological resource for arms control, verification technologies, a number of intelligence technologies, and strategic defense technologies.

The intellectual strength of our laboratories in all these technologies grows out of close interaction between them and a vibrant program of nuclear weapons research, development, and testing. We can retain a cadre of first-class weapons experts at our national laboratories through a combination of support for vigorous research programs in the above areas, and support for closely related research that meets specific civilian needs.

Examples of the latter would include laser science and technology, advanced computational science and technology, fluid dynamics and three-dimensional hydrodynamics, research on high-temperature ceramic materials, and geophysics research, drilling technology, and studies of transport of contaminants in subsurface environments, to name a few.

In areas such as these, maintaining technical excellence at the laboratories purely for civilian applications can provide the additional benefit of retaining trained personnel as insurance against unforeseen catastrophic shifts in international relations.

Let us talk about civilian missions. As the above examples indicate, it is dead wrong to suppose that fundamental research performed for defense applications does not contribute equally well to civilian applications crucial to our economic competitiveness. We must be very cautious before we allow the elimination at our laboratories of any capacity that may be freed up by a possible reduction in their defense missions.

It is essential that the human and technical resources at our laboratories be redirected to strengthen our badly needed ability to develop new technologies for civilian application. We need to regain our world leadership in applying technology, and we need our laboratories at full strength to do so.

The reasons the national laboratories are so important here can be illustrated by the following statistics. Our laboratories currently employ over 16,000 researchers with advanced degrees in science and technology, more than 8,500 of whom have doctorate degrees. More than 50 Nobel Prizes have been awarded for work related to that performed at the national laboratories, and 15 Nobel Prizes have been awarded for work directly performed at these same laboratories.

No single laboratory or group of laboratories anywhere in the country can compare with this resource or match its record of accomplishment. So the country simply cannot afford to fritter away such a precious national asset.

In that regard, I would like to focus on technology transfer. I refer now to my notes, which I believe you have in your hand, and I will try to abbreviate here.

The potential of this asset to contribute to national economic competitiveness is further evidenced by the impressive track record the DOE scientists and engineers have for excellence and innovation. Our laboratories are star performers in the R&D 100 Awards, an international competition that "Research and Development Magazine" conducts each year to identify the hundred new products, processes and materials deemed most significant from a technical perspective. Over the past 27 years, DOE laboratories and facilities have won more than 275 R&D 100 Awards.

Over 140 spinoff companies based on technologies developed by DOE have been formed since 1985 alone.

I am committed to seeing that benefits of DOE-sponsored technologies are realized even more effectively by the U.S. economy. A key help in this regard has been the National Competitiveness Technology Transfer Act of 1989. This act made technology transfer a mission of all DOE laboratories and provided a new mechanism for laboratory/industry cooperation, called Cooperative Research and Development Agreements.

I think this committee deserves a great deal of credit for its foresight in sponsoring this particular act and helping us achieve its objectives.

I have also been working to make sure that industry becomes better informed about the capabilities of our laboratories. For example, last March I hosted a technology transfer round-table in Washington with the Secretary of Commerce, and Senators Domenici and Bingaman of this committee were in attendance.

Another success involves industry as partners with the national laboratories in a program of High-Temperature Superconductivity Pilot Centers. In the last year alone, 24 agreements were signed between industry and the High-Temperature Superconductivity Pilot Centers, with 50 percent cost-sharing.

This past week, DOE took some concrete steps to further improve the access of industry to state-of-the-art technology, and here on Capitol Hill, with many of your colleagues present, we signed two agreements. They were well announced, I think, in the media.

In the area of education, the Department of Energy has taken a strong leading role in the development of programs to improve science and mathematics education in the United States. With the Presidential and Governors' national goal of being No. 1 in math and science by the year 2000, we believe this is a major step forward in helping the President and the governors carry out this objective.

As a result, on May 21, I issued a Secretary of Energy Notice establishing education as a primary departmental mission, and encouraging education outreach efforts on the part of all DOE and contractor personnel. The law establishing the Department of Energy allows me to take that action when it is clearly in the best interest of the Department to help build the base of human resources necessary to achieve its objectives.

The notice that I put out culminated a year of important changes in the Department's education programs, the blueprint of which came out of our Math and Science Education Conference held at the Lawrence Hall of Science in Berkeley last October, just 10 days after the historic meeting at Charlottesville.

The national laboratories have traditionally had education as one of their missions, but the historic focus of their efforts has been at the undergraduate, graduate, and post-doctoral level. Based on recommendations at the Berkeley conference, the Department has begun significant expansion of support for precollege science education programs at the national laboratories, including programs specifically designed for precollege math and science teachers.

Now I would just like to name a few of those that we have established already that are underway and very exciting. The Bay Area Science and Technology Education Collaboration, in which four national laboratories in California are working in the Oakland Bay area. We have a program for over 2,700 teachers in the Oakland Unified School District.

The New Explorers Program, involving the Chicago Public Schools, Argonne and Fermi National Laboratories, and 10 other Chicago institutions, has already reached over 15,000 students this year.

An academy for math and science teachers in Chicago, spawned by Dr. Leon Lederman, one of our Nobel Laureates and a former Director of the FermiLab, and supported by the Department of Energy, the State of Illinois, the City of Chicago, and the private sector, will come to fruition very soon. And with the help of this Committee, we will be able to have a formal inauguration of this academy, and get it started to teach the 15,000 teachers there in the Chicago area from K to 12 something about science and mathematics, for the first time. They do not know very much now, and they know it.

They are very receptive to this and are very excited about going out tomorrow and helping the Governor and the members of the school boards, business and industry in Illinois, to embark on this very important pilot program, which will demonstrate to the Nation that we can really move a city that is at the very bottom edge of the education rung in math and science.

The OPTIONS Program of Pacific Northwest Laboratories will reach thousands of Hispanic, black and native American students in the States of Washington and Oregon, as will a partnership involving Los Alamos and Sandia National Laboratories will reach middle schools in New Mexico and native American schools in Northern New Mexico and Arizona.

This latter partnership was formed this morning by a memorandum of understanding (MOU) between myself and Secretary of Interior Manuel Lujan. The MOU provides for a continuing relationship between DOE's Los Alamos and Sandia National Laboratories and the Indian Nations' schools.

We are very excited about this, and it can be a template for others as we expand the math and science education initiative under the Federal Coordinating Committee on Science, Engineering, and Technology under Dr. Bromley, on a panel which I chair. We are, for your interest, moving on it aggressively to be able to hopefully coordinate all the Government agencies in their partnerships with the private sector for both human and material resources.

The strides that the Department of Energy has made in the past year to expand its already significant educational base would not have been possible without the excellent foundation of science education programs underway for many years. It is not just a matter of adding new dollars, but rather, it is more important to add the human resources which are ready to volunteer their time to come forward and help the private sector.

Research and development, now. I would like to address that in the context of environmental restoration and waste management. We have had many accomplishments in this area in promoting technology transfer and education to provide a foundation for enhanced efforts in this area.

The Nation is facing a crisis. We do not have enough skills. We have thousands of landfills and other sites where wastes have been dumped and abandoned, and our efforts to address this national problem have been hampered by a lack of fundamental understanding of subsurface environments, a paucity of cleanup technologies and a shortage of trained personnel both to perform the needed research and development and to carry out remediation activity.

I would have to say that we need technicians at the high school graduate level in as many numbers as can come forward. We need them now. They are the kinds of skills that should be attractive to youngsters to come into these fields of environmental restoration and waste management and help the Nation out, not only here but abroad as well, to help other nations come out of the nightmare that some of them are facing in environmental damage. We have outlined in the brief oral statement here some of the things we are doing in that regard, and I ask you to refer to my notes in that area for a continuation of this theme.

Now, the next point I would like to talk about is the Secretary of Energy Advisory Board and its challenge to address the issue of the national laboratories in the next decade. We have established this Secretary of Energy Advisory Board with its primary focus in the next year on exactly what this hearing is all about. Whither goest the laboratories in the future, and how do we maintain this absolute jewel in our society to help take the Nation on at full pace and running as we go into the next century?

I have provided a list of names and current positions of some of the members of the planning group for this study in my formal statement, and I think you will agree that it is a very balanced and expert group. I expect to have their proposal for the scope and organization of a study before the end of this summer.

I will be in Chicago tomorrow at the Argonne National Laboratory with my entire panel, addressing the scope and organization of that study and giving them the kind of guidance that I would hope to augment by information coming out of this hearing today.

I heard Senator Ford give us some very good ideas, and I would like to get those questions because I will take them out to Argonne with me tomorrow and make sure they are factored into their review of how we make sure we maintain this incredible national resource.

Since this distinguished group of individuals is busy trying to formulate advice to me on the most effective scope of the study, I do not want to preempt their deliberations, but I would like to take some of those issues that I believe are on their minds and will be putting into a draft charge for my review and approval, together with these kinds of things in mind and added to by any that this Committee may have.

Where are the current and likely future strengths of the national laboratories? What set of missions would they best be suited for in the 1990's? How are relationships and partnerships among performers of research, or between performers and users of research likely to change in the coming decade? What can DOE do to facilitate closer interaction between laboratory researchers and researchers at universities or in industry?

As the research missions of the national laboratories evolve to meet the challenges of the 1990's and perhaps grow even more diverse, how should the management of the laboratories by DOE evolve, and so forth? These are just a few of the questions, and we will be adding more to it as our deliberations continue tomorrow. Then hopefully we will be able to get this underway with some answers in the next 6 months to a year's time.

These are a few of the thoughts with which I want to open my discussion with you all here today. They by no means touch everything, but I think it gives you an idea that I am on the same wavelength, I believe, that this Committee is on, as expressed by your opening comments. I feel that we are underway with a whole new and exciting role for all of our national laboratories, in particular those that have been labeled as the bomb laboratories in the past, which is simply fast becoming a misnomer.

I think it is time to recognize that these are incredibly wonderful people with peace and prosperity for not only this country but mankind on their minds, and that those resources do not want to be lost, as Senator Domenici indicated happened at MIT. We must retain that for the good of the Nation.

With those brief comments, I will open myself to any questions you may have.

[The prepared statement of Secretary Watkins follows:]

ORAL STATEMENT OF ADMIRAL JAMES D. WATKINS, U.S. NAVY (RETIRED) BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT, SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

JULY 25, 1990

I. INTRODUCTION

I AM PLEASED TO BE INVITED TO TESTIFY BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT ON THE FUTURE OF THE DOE NATIONAL LABORATORY COMPLEX.

I FIRMLY BELIEVE THAT WE STAND ON THE THRESHOLD OF AN UNPARALLELED DECADE OF ADVANCES IN RESEARCH AND EDUCATION IN THE 1990S. THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES HAVE A VITAL ROLE TO PLAY IN ACHIEVING THE PROMISE OF THE 1990S--AND SECURING A FUTURE MARKED BY PEACE (THROUGH A STRONG AND EFFECTIVE DEFENSE) AND PROSPERITY (THROUGH AFFORDABLE AND ENVIRONMENTALLY BENIGN ENERGY TECHNOLOGIES).

OUR DEVELOPING NATIONAL ENERGY STRATEGY IS DOCUMENTING THE TREMENDOUS NEED FOR IMPROVEMENTS IN ENERGY TECHNOLOGY ACROSS THE BOARD--FOR EVERY ENERGY SUPPLY OPTION, TO IMPROVE ENERGY EFFICIENCY, AND TO PROTECT AND IMPROVE OUR ENVIRONMENT. IT IS MY HOPE THAT THE DEVELOPMENT OF THE NATIONAL ENERGY STRATEGY WILL LEAD TO A SEARCHING REEVALUATION OF DOE'S TRADITIONAL RESEARCH MISSIONS AND ACTIVITIES, AS WELL AS A DEPARTMENT-WIDE R&D STRATEGY THAT WILL ALLOW DOE TO TAKE AN INTEGRATED APPROACH TO SPURRING THE DEVELOPMENT OF THE ENERGY TECHNOLOGIES THAT WE WILL NEED IN THE NEXT CENTURY.

THE DOE LABORATORIES WILL PLAY A CRUCIAL ROLE IN THE DEVELOPMENT OF THESE TECHNOLOGIES. AS I DISCUSS THESE NATIONAL LABORATORIES WITH YOU TODAY, I WILL REFER TO ALL OF THE DEPARTMENT'S LABORATORIES WHEN SPEAKING ABOUT TOPICS SUCH AS EDUCATION AND TECHNOLOGY TRANSFER. WHEN I SPEAK OF THE LABORATORIES WITH MISSIONS IN NATIONAL DEFENSE, I WILL BE SPEAKING MORE SPECIFICALLY ABOUT THE THREE LABORATORIES WITH NUCLEAR WEAPONS PROGRAMS--LOS ALAMOS NATIONAL LABORATORY, LAWRENCE LIVERMORE NATIONAL LABORATORY, AND SANDIA NATIONAL LABORATORY. THE SUBCOMMITTEE SHOULD BE AWARE, THOUGH, THAT EVEN THESE THREE LABORATORIES HAVE SUBSTANTIAL PROGRAMS IN NON-NUCLEAR WEAPONS TECHNOLOGIES, EQUALLING ABOUT HALF OF THEIR OVERALL RESEARCH PROGRAM, AND THAT THEY ARE ALREADY MAKING IMPORTANT CONTRIBUTIONS TO THE DEVELOPMENT OF ENERGY TECHNOLOGY.

II. DEFENSE MISSIONS

IN THE WORLD OF THE 1990S, THE NEED FOR A STRONG DEFENSE TECHNOLOGY BASE WILL REMAIN, EVEN THOUGH THE PRIORITIES AMONG RESEARCH AREAS RELATED TO NUCLEAR WEAPONS WILL SHIFT. THE NEW PRIORITIES WILL INCLUDE CONTINUED ENHANCEMENT OF

SAFETY, SECURITY, SURVIVABILITY, AND COMMAND AND CONTROL OF NUCLEAR WEAPONS. THE MANUFACTURE OF WARHEADS WILL BE INCREASINGLY DOMINATED BY ISSUES OF WASTE MINIMIZATION IN UP-FRONT DESIGN, WASTE MANAGEMENT IN DOWNSTREAM MATERIALS PROCESSING, AND OTHER ENVIRONMENTAL IMPACTS. AND NEGOTIATED CUTS IN WORLDWIDE STOCKPILES OF NUCLEAR WEAPONS WILL SET THE OVERALL TONE FOR DEFENSE DECISION MAKING IN THE UNITED STATES. TO PRESERVE OUR NATIONAL SECURITY AND ENHANCE GLOBAL STABILITY, THE COMPETENCIES AT OUR NUCLEAR WEAPONS LABORATORIES WILL BECOME MORE IMPORTANT THAN EVER BEFORE. AS THE SIZE OF THE STOCKPILE DECREASES, CONSIDERATIONS SUCH AS WEAPONS RELIABILITY AND SAFETY WILL LOOM LARGER. MAINTENANCE OF A COMPETENT CADRE OF NUCLEAR WEAPONS EXPERTS IS ESSENTIAL IF THE UNITED STATES IS TO HAVE CONFIDENCE IN A NUCLEAR DETERRENT THAT WILL REMAIN A KEY PART OF ITS DEFENSE STRATEGY, ALBEIT REDUCED IN SIZE AND SCOPE, FOR YEARS TO COME.

ALONG WITH EXPERTISE IN NUCLEAR WEAPONS DESIGN AND MANUFACTURE, THE 1990S WILL REQUIRE RELATED EXPERTISE THAT CURRENTLY IS CENTERED AT THE DOE NATIONAL DEFENSE LABORATORIES. THESE LABORATORIES ARE THE NATION'S PRIME TECHNOLOGICAL RESOURCE FOR ARMS CONTROL, VERIFICATION TECHNOLOGIES, A NUMBER OF INTELLIGENCE TECHNOLOGIES, AND STRATEGIC DEFENSE TECHNOLOGIES. THE INTELLECTUAL STRENGTH OF THE LABORATORIES IN ALL OF THESE TECHNOLOGIES GROWS OUT OF CLOSE INTERACTION BETWEEN THEM AND A VIBRANT PROGRAM OF NUCLEAR WEAPONS RESEARCH, DEVELOPMENT, AND TESTING.

WE CAN RETAIN A CADRE OF FIRST-CLASS WEAPONS EXPERTS AT OUR NATIONAL LABORATORIES THROUGH A COMBINATION OF SUPPORT FOR VIGOROUS RESEARCH PROGRAMS IN THE ABOVE AREAS AND SUPPORT FOR CLOSELY RELATED RESEARCH THAT MEETS SPECIFIC CIVILIAN NEEDS. EXAMPLES OF THE LATTER WOULD INCLUDE LASER SCIENCE AND TECHNOLOGY, ADVANCED COMPUTATIONAL SCIENCE AND TECHNOLOGY, FLUID DYNAMICS AND THREE-DIMENSIONAL HYDRODYNAMICS, RESEARCH ON HIGH-TEMPERATURE CERAMIC MATERIALS, AND GEOPHYSICS RESEARCH, DRILLING TECHNOLOGY, AND STUDIES OF TRANSPORT OF CONTAMINANTS IN SUBSURFACE ENVIRONMENTS, TO NAME A FEW. IN AREAS SUCH AS THESE, MAINTAINING TECHNICAL EXCELLENCE AT THE LABORATORIES PURELY FOR CIVILIAN APPLICATIONS CAN PROVIDE THE ADDITIONAL BENEFIT OF RETAINING TRAINED PERSONNEL AS INSURANCE AGAINST UNFORSEEN CATASTROPHIC SHIFTS IN INTERNATIONAL RELATIONS.

III. CIVILIAN MISSIONS

AS THE ABOVE EXAMPLES INDICATE, IT IS DEAD WRONG TO SUPPOSE THAT FUNDAMENTAL RESEARCH PERFORMED FOR DEFENSE APPLICATIONS DOES NOT CONTRIBUTE EQUALLY WELL TO CIVILIAN APPLICATIONS CRUCIAL TO OUR ECONOMIC COMPETITIVENESS. WE MUST BE VERY CAUTIOUS BEFORE WE ALLOW THE ELIMINATION AT OUR LABORATORIES OF ANY CAPACITY THAT MAY BE FREED UP BY A POSSIBLE REDUCTION IN THEIR DEFENSE MISSIONS. IT IS ESSENTIAL THAT THE HUMAN AND TECHNICAL RESOURCES AT OUR LABORATORIES BE REDIRECTED TO STRENGTHEN OUR BADLY NEEDED ABILITY TO DEVELOP

NEW TECHNOLOGIES FOR CIVILIAN APPLICATION. WE NEED TO REGAIN OUR WORLD LEADERSHIP IN APPLYING TECHNOLOGY, AND WE NEED OUR LABORATORIES AT FULL STRENGTH TO DO SO.

THE REASON THAT THE NATIONAL LABORATORIES ARE SO IMPORTANT HERE CAN BE ILLUSTRATED BY THE FOLLOWING STATISTICS. OUR LABORATORIES CURRENTLY EMPLOY OVER 16,000 RESEARCHERS WITH ADVANCED DEGREES IN SCIENCE AND TECHNOLOGY, MORE THAN 8,500 OF WHOM HAVE DOCTORATE DEGREES. MORE THAN 50 NOBEL PRIZES HAVE BEEN AWARDED FOR WORK RELATED TO THAT PERFORMED AT THE NATIONAL LABORATORIES, AND 15 NOBEL PRIZES HAVE BEEN AWARDED FOR WORK DIRECTLY PERFORMED AT THESE LABORATORIES. NO SINGLE LABORATORY OR GROUP OF LABORATORIES ANYWHERE IN THE COUNTRY CAN COMPARE WITH THIS RESOURCE OR MATCH ITS RECORD OF ACCOMPLISHMENT. THIS COUNTRY CANNOT AFFORD TO FRITTER AWAY SUCH A PRECIOUS NATIONAL ASSET.

A. TECHNOLOGY TRANSFER

THE POTENTIAL OF THIS ASSET TO CONTRIBUTE TO NATIONAL ECONOMIC COMPETITIVENESS IS FURTHER EVIDENCED BY THE IMPRESSIVE TRACK RECORD THAT DOE SCIENTISTS AND ENGINEERS HAVE FOR EXCELLENCE IN INNOVATION. THE DOE LABORATORIES ARE STAR PERFORMERS IN THE R&D-100 AWARDS--AN INTERNATIONAL COMPETITION THAT RESEARCH AND DEVELOPMENT MAGAZINE CONDUCTS EACH YEAR TO IDENTIFY THE 100 NEW PRODUCTS, PROCESSES, AND MATERIALS DEEMED MOST SIGNIFICANT FROM A TECHNICAL PERSPECTIVE. OVER THE PAST 27 YEARS, DOE LABORATORIES AND FACILITIES HAVE WON MORE THAN 275 R&D-100 AWARDS. OVER 140 SPIN-OFF COMPANIES BASED ON TECHNOLOGIES DEVELOPED BY DOE HAVE BEEN FORMED SINCE 1985. I AM PROUD OF DOE'S TRACK RECORD OF DEVELOPING TECHNOLOGIES THAT HAVE CREATED NEW JOBS AND WEALTH IN THE UNITED STATES.

I AM COMMITTED TO SEE THAT THE BENEFITS OF DOE-SPONSORED RESEARCH ARE REALIZED EVEN MORE EFFECTIVELY BY THE U.S. ECONOMY. UNLESS THE RESULTS OF OUR RESEARCH ARE PRODUCTIVELY USED BY U.S. INDUSTRY AND THE CONSUMER, WE ARE WASTING THE TAXPAYER'S INVESTMENT IN THAT RESEARCH. ACCORDINGLY, I HAVE GIVEN HIGH PRIORITY AT THE DEPARTMENT OF ENERGY TO DEVELOPING STRATEGIES TO PROMOTE TECHNOLOGY TRANSFER TO EVEN GREATER DEGREES.

A KEY HELP IN THIS REGARD HAS BEEN THE NATIONAL COMPETITIVENESS TECHNOLOGY TRANSFER ACT OF 1989. THIS ACT MADE TECHNOLOGY TRANSFER A MISSION OF ALL DOE LABORATORIES, AND PROVIDED A NEW MECHANISM FOR LABORATORY-INDUSTRY COOPERATION--CALLED COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS (CRADAS). THE DOE IS MOVING AGGRESSIVELY TO IMPLEMENT THE ACT. WE HAVE MOBILIZED OVER 100 PEOPLE IN THE DEPARTMENT AND ITS LABORATORIES TO DEVELOP A PROGRAM THAT WILL PROVIDE A FAST, FLEXIBLE, AND PREDICTABLE ENVIRONMENT FOR TECHNOLOGY TRANSFER FROM OUR LABORATORIES.

I HAVE ALSO BEEN WORKING TO MAKE SURE THAT INDUSTRY BECOMES BETTER INFORMED ABOUT THE CAPABILITIES OF OUR LABORATORIES. FOR EXAMPLE, LAST MARCH I HOSTED A TECHNOLOGY TRANSFER ROUND TABLE IN WASHINGTON WITH THE SECRETARY OF COMMERCE AND SENATORS DOMENICI AND BINGAMAN. ANOTHER SUCCESS IN INVOLVING INDUSTRY AS PARTNERS WITH THE NATIONAL LABORATORIES IS OUR PROGRAM OF HIGH-TEMPERATURE SUPERCONDUCTIVITY PILOT CENTERS. THREE SUCH CENTERS WERE LAUNCHED IN LATE 1988 AT LOS ALAMOS NATIONAL LABORATORY, ARGONNE NATIONAL LABORATORY, AND OAK RIDGE NATIONAL LABORATORY. IN THE FIRST YEAR, 24 AGREEMENTS WERE SIGNED BETWEEN INDUSTRY AND THE HIGH-TEMPERATURE SUPERCONDUCTIVITY PILOT CENTERS, WITH 50 PERCENT COST-SHARING.

THIS PAST WEEK, DOE TOOK SOME CONCRETE STEPS TO FURTHER IMPROVE THE ACCESS OF INDUSTRY TO STATE-OF-THE-ART TECHNOLOGY DEVELOPED IN OUR NATIONAL LABORATORIES. WE SIGNED TWO AGREEMENTS, ONE WITH A CONSORTIUM OF SPECIALTY METALS INDUSTRIES AND THE OTHER WITH A CONSORTIUM OF ADVANCED MANUFACTURING INDUSTRIES, TO PROVIDE THEM WITH TECHNOLOGY DEVELOPED IN THE DEFENSE PROGRAMS OF THE DEPARTMENT OF ENERGY. THIS SUCCESS IN FINDING WAYS TO EXTRACT TECHNOLOGY OF COMMERCIAL VALUE FROM THE WEAPONS COMPLEX, AND PLACING THAT TECHNOLOGY IN THE HANDS OF AMERICAN INDUSTRY, REPRESENTS ANOTHER IMPORTANT FACET OF DOE'S OVERALL PROGRAM OF FACILITATING TECHNOLOGY TRANSFER FROM ITS LABORATORIES AND PRODUCTION FACILITIES.

B. EDUCATION

THE DEPARTMENT OF ENERGY HAS ALSO TAKEN A STRONG LEADING ROLE IN THE DEVELOPMENT OF PROGRAMS TO IMPROVE SCIENCE AND MATHEMATICS EDUCATION IN THE UNITED STATES. LAST YEAR, THE PRESIDENT AND THE NATION'S GOVERNORS ADOPTED SIX FORWARD-LOOKING AND CHALLENGING GOALS, ONE OF WHICH IS EXCELLENCE IN MATHEMATICS AND SCIENCE EDUCATION. THE NATIONAL LABORATORIES ARE UNIQUELY POSITIONED TO HELP THE UNITED STATES REACH THIS OBJECTIVE, AND THEIR HELP COULD NOT BE MORE TIMELY.

ON MAY 21, 1990, I ISSUED A SECRETARY OF ENERGY NOTICE ESTABLISHING EDUCATION AS A PRIMARY DEPARTMENTAL MISSION AND ENCOURAGING EDUCATION OUTREACH EFFORTS ON THE PART OF ALL DOE AND CONTRACT PERSONNEL. THIS NOTICE CULMINATED A YEAR OF IMPORTANT CHANGES IN THE DEPARTMENT'S EDUCATION PROGRAMS. THE BLUEPRINT FOR MANY OF THOSE CHANGES WAS PROVIDED BY THE MATH/SCIENCE EDUCATION ACTION CONFERENCE HELD AT THE LAWRENCE HALL OF SCIENCE IN BERKELEY, CALIFORNIA LAST OCTOBER, JUST TEN DAYS AFTER THE PRESIDENT'S HISTORIC EDUCATION SUMMIT WITH THE GOVERNORS.

THE NATIONAL LABORATORIES HAVE TRADITIONALLY HAD EDUCATION AS ONE OF THEIR MISSIONS, BUT THE HISTORIC FOCUS OF THEIR EFFORTS HAS BEEN AT THE UNDERGRADUATE, GRADUATE AND POSTDOCTORAL LEVEL. BASED ON THE RECOMMENDATIONS OF THE BERKELEY CONFERENCE, THE DEPARTMENT HAS BEGUN A SIGNIFICANT EXPANSION

OF SUPPORT FOR PRECOLLEGE SCIENCE EDUCATION PROGRAMS AT THE NATIONAL LABORATORIES, INCLUDING PROGRAMS SPECIFICALLY DESIGNED FOR PRECOLLEGE MATH AND SCIENCE TEACHERS. IN THIS, SPECIAL EMPHASIS HAS BEEN PLACED FOR FY 1991 ON THE FURTHER DEVELOPMENT OF PARTNERSHIPS BETWEEN DOE LABORATORIES AND INNER-CITY AND RURAL SCHOOLS, WITH A GOAL OF REVITALIZING MATH AND SCIENCE EDUCATION. NEW LABORATORY INITIATIVES INCLUDE:

- THE BAY AREA SCIENCE AND TECHNOLOGY EDUCATION COLLABORATION, IN WHICH FOUR NATIONAL LABORATORIES IN THE CALIFORNIA BAY AREA (LAWRENCE BERKELEY, LAWRENCE LIVERMORE, SANDIA-LIVERMORE, AND STANFORD LINEAR ACCELERATOR LABORATORIES) HAVE JOINED THE PRIVATE SECTOR TO SPONSOR ENRICHMENT PROGRAMS FOR ALL 2,700 TEACHERS IN THE OAKLAND UNIFIED SCHOOL DISTRICT.

- "THE NEW EXPLORERS PROGRAM" INVOLVING THE CHICAGO PUBLIC SCHOOLS, ARGONNE AND FERMI NATIONAL LABORATORIES, AND TEN OTHER CHICAGO INSTITUTIONS INVOLVED IN SCIENCE EDUCATION, WHICH HAS REACHED OVER 15,000 STUDENTS ALREADY THIS YEAR;

- AN ACADEMY FOR MATHEMATICS AND SCIENCE TEACHERS IN CHICAGO, BEGUN BY LEON LEDERMAN, FORMER DIRECTOR OF FERMILAB, AND SUPPORTED BY DOE, THE STATE OF ILLINOIS, THE CITY OF CHICAGO, AND THE PRIVATE SECTOR. TOMORROW, I WILL PARTICIPATE IN THE FORMAL INAUGURATION OF THIS ACADEMY.

- THE "OPTIONS" PROGRAM AT PACIFIC NORTHWEST LABORATORY THAT WILL REACH THOUSANDS OF HISPANIC, BLACK, AND NATIVE AMERICAN STUDENTS IN THE STATES OF WASHINGTON AND OREGON; AND

- A PARTNERSHIP INVOLVING LOS ALAMOS AND SANDIA NATIONAL LABORATORIES, MIDDLE SCHOOLS IN NEW MEXICO, AND NATIVE AMERICAN SCHOOLS IN NORTHERN NEW MEXICO AND ARIZONA.

THIS LATTER PARTNERSHIP WAS FORMALIZED THIS MORNING BY A MEMORANDUM OF UNDERSTANDING (MOU) THAT I SIGNED WITH SECRETARY OF THE INTERIOR MANUEL LUJAN, JR. THE MOU PROVIDES FOR A CONTINUING RELATIONSHIP BETWEEN DOE'S LOS ALAMOS AND SANDIA NATIONAL LABORATORIES AND THE INDIAN NATION SCHOOLS OPERATED BY THE BUREAU OF INDIAN AFFAIRS.

THE STRIDES THAT THE DEPARTMENT OF ENERGY HAS MADE IN THE PAST YEAR TO EXPAND ITS ALREADY SIGNIFICANT EDUCATIONAL BASE WOULD NOT HAVE BEEN POSSIBLE WITHOUT THE EXCELLENT FOUNDATION OF SCIENCE EDUCATION PROGRAMS UNDERWAY FOR MANY YEARS AT THE NATIONAL LABORATORIES. IT IS NOT JUST A MATTER OF ADDING NEW DOLLARS. EACH DOLLAR SPENT ON A TEACHER OR STUDENT AT THE LABORATORIES IS HIGHLY LEVERAGED. THE FACILITIES, THE EQUIPMENT, AND THE SCIENTISTS ARE ALREADY

THERE. OUR APPROACH IS TO USE THE IMMENSE RESOURCES AT OUR FINGERTIPS MORE CREATIVELY AND EFFECTIVELY--IN PARTNERSHIP WITH OTHER FEDERAL AGENCIES, THE STATES, AND THE PRIVATE SECTOR--TO ACHIEVE THE NATION'S EDUCATION GOALS.

IV. RESEARCH AND DEVELOPMENT ON ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

THE DEPARTMENT OF ENERGY'S ACCOMPLISHMENTS TO DATE IN PROMOTING TECHNOLOGY TRANSFER AND EDUCATION PROVIDE A FOUNDATION FOR THE ENHANCED EFFORTS I SEE DOE MAKING IN THE COMING YEARS TO PROMOTE RESEARCH AND DEVELOPMENT ON ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT. OUR NATION IS FACING A CRISIS IN THIS AREA--NOT ONLY WITHIN THE DOE DEFENSE PRODUCTION COMPLEX, BUT IN THOUSANDS OF LANDFILLS AND OTHER SITES WHERE WASTES HAVE BEEN DUMPED OR ABANDONED. OUR EFFORTS TO ADDRESS THIS NATIONAL PROBLEM HAVE BEEN HAMPERED BY A LACK OF FUNDAMENTAL UNDERSTANDING OF SUBSURFACE ENVIRONMENTS, A PAUCITY OF CLEAN-UP TECHNOLOGIES, AND A SHORTAGE OF TRAINED PERSONNEL BOTH TO PERFORM THE NEEDED RESEARCH AND DEVELOPMENT AND TO CARRY OUT REMEDIATION ACTIVITIES.

I BELIEVE THAT OVER THE NEXT 20 TO 30 YEARS THE FIELD OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT WILL BE ONE OF THE MAJOR GROWTH AREAS FOR SCIENTIFIC AND TECHNICAL EMPLOYMENT IN THE UNITED STATES, AND THAT THE NATIONAL LABORATORIES WILL PLAY AN IMPORTANT ROLE IN SHAPING THAT GROWTH. THEY WILL DO THIS IN TWO WAYS:

- FIRST, BY BRINGING TOGETHER THE FINEST TALENT IN THE FEDERAL RESEARCH COMPLEX, THE UNIVERSITY COMMUNITY, AND INDUSTRY TO CONTRIBUTE TO ENVIRONMENTAL REMEDIATION RESEARCH AND DEVELOPMENT, USING OUR FACILITIES AS TEST BED SITES; AND

- SECOND, BY IMPLEMENTING A CADRE OF STATE-OF-THE-ART EDUCATION AND TRAINING PROGRAMS TO BUILD THE RESEARCH AND TECHNICAL WORKFORCE WE WILL NEED IN BOTH NEAR AND LONG TERMS TO MEET THESE CHALLENGES.

V. SECRETARY OF ENERGY ADVISORY BOARD STUDY OF THE NATIONAL LABORATORIES

IN EDUCATION AND TECHNOLOGY TRANSFER, THEN, THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES ARE ALREADY RISING TO THE CHALLENGES OF THE 1990S. WITH APPROPRIATE SUPPORT FROM THE CONGRESS FOR THE PRESIDENT'S REQUESTED BUDGETS, I BELIEVE THAT THE NATIONAL LABORATORIES WILL PROVE EQUAL TO THE CHANGING DEFENSE REQUIREMENTS OF THE NEXT DECADE AS WELL. WHY, THEN, HAVE I COMMISSIONED AN OVERALL REVIEW OF THE MANAGEMENT OF THE NATIONAL LABORATORY COMPLEX FROM THE SECRETARY OF ENERGY ADVISORY BOARD?

MY ANSWER IS THAT, TO MEET THE CHALLENGES OF A RAPIDLY CHANGING WORLD IN AN EFFECTIVE MANNER, IT IS NOT ENOUGH TO REVITALIZE, EXPAND, OR REDIRECT

INDIVIDUAL FACETS OF THE NATIONAL LABORATORY SYSTEM. FROM TIME TO TIME, IT IS NECESSARY TO STEP BACK AND TAKE A FRESH LOOK AT THE PRINCIPLES GUIDING THE MANAGEMENT OF THE LABORATORY COMPLEX, AND TO ASK WHETHER A DIFFERENT APPROACH WOULD BETTER SUSTAIN THE LABORATORIES' EXCELLENCE INTO THE FUTURE.

WITH THIS GOAL IN MIND, I ASKED A SUBGROUP OF THE SECRETARY OF ENERGY ADVISORY BOARD TO DEVELOP A TASKING STATEMENT FOR SUCH A STUDY, DRAWING ON THEIR UNIQUE PERSPECTIVES AND EXPERTISE IN RESEARCH MANAGEMENT. A LISTING OF THE NAMES AND CURRENT POSITIONS OF THE MEMBERS OF THE PLANNING GROUP FOR THIS STUDY IS CONTAINED IN MY FORMAL STATEMENT. I THINK YOU WILL AGREE WITH ME THAT IT IS A BALANCED AND EXPERT GROUP.

I EXPECT TO HAVE THEIR PROPOSAL FOR THE SCOPE AND ORGANIZATION OF A STUDY BEFORE THE END OF THE SUMMER. ONCE I REVIEW, MODIFY, AND APPROVE THE CHARGE TO THE PANEL, I HOPE TO SET THE STUDY UP QUICKLY AND HAVE A PRELIMINARY REPORT FROM THE PANEL WITHIN SIX MONTHS OF ITS FORMATION.

SINCE THIS DISTINGUISHED GROUP OF INDIVIDUALS ARE BUSY TRYING TO FORMULATE ADVICE TO ME ON THE MOST EFFECTIVE SCOPE OF THIS STUDY, I DON'T WANT TO PREEMPT THEIR DELIBERATIONS BY RULING PARTICULAR QUESTIONS IN OR OUT OF THE STUDY THIS MORNING. BUT I WOULD LIKE TO PLACE BEFORE YOU SOME ISSUES THAT I BELIEVE SHOULD BE ON THEIR MINDS AS THEY PUT TOGETHER A DRAFT CHARGE FOR MY REVIEW AND APPROVAL.

- WHERE ARE THE CURRENT AND LIKELY FUTURE STRENGTHS OF THE NATIONAL LABORATORIES? WHAT SET OF MISSIONS WOULD THEY BE BEST SUITED TO IN THE 1990S?

- HOW ARE RELATIONSHIPS AND PARTNERSHIPS AMONG PERFORMERS OF RESEARCH, OR BETWEEN PERFORMERS AND USERS OF RESEARCH, LIKELY TO CHANGE IN THE COMING DECADE? WHAT CAN DOE DO TO FACILITATE CLOSER INTERACTIONS BETWEEN LABORATORY RESEARCHERS AND RESEARCHERS AT UNIVERSITIES OR IN INDUSTRY?

- AS THE RESEARCH MISSIONS OF THE NATIONAL LABORATORIES EVOLVE TO MEET THE CHALLENGES OF THE 1990S, AND PERHAPS GROW MORE DIVERSE, HOW SHOULD THE MANAGEMENT OF THE LABORATORIES BY DOE EVOLVE?

I BELIEVE THAT THESE ARE ONLY A FEW OF THE MANY CHALLENGING QUESTIONS THAT CONFRONT THE NATIONAL LABORATORIES. I HOPE THAT MY COMMENTS HERE THIS MORNING HAVE SERVED TO CRYSTALLIZE FOR YOU SOME OF MY OVERALL VIEWS ABOUT THE ACCOMPLISHMENTS OF THE NATIONAL LABORATORIES, AS WELL AS SOME OF THE OPPORTUNITIES THAT LIE BEFORE THEM. I WELCOME YOUR SUGGESTIONS OF ISSUES THAT YOU BELIEVE I AND THE PLANNING GROUP FOR THIS STUDY SHOULD CONSIDER AS WE FINALIZE THE SCOPE OF THE ACTIVITY AND MOVE FORWARD WITH ITS EXECUTION.

THANK YOU VERY MUCH.

TESTIMONY OF ADMIRAL JAMES D. WATKINS, U.S. NAVY (RETIRED)
BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT, SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

JULY 25, 1990

I. Introduction

I am pleased to be invited to testify before the Subcommittee on Energy Research and Development on the future of the DOE National Laboratory complex, and in particular the future of the DOE nuclear weapons laboratories.

For some time now, I have been thinking about the future research agenda for the Department of Energy. My thinking has been stimulated by a number of sources. One prime source is the imposing set of problems that I confront daily at the Department of Energy. They are a constant reminder of how little we know about topics as diverse as epidemiology, atmospheric and climate science, biotechnology, and materials chemistry--just to name a few. A second source of new ideas for the Department's research agenda has been the public input received by DOE for the development of a National Energy Strategy. My thinking has also been stimulated by viewpoints and advice that I have received from numerous distinguished scientists and engineers, including members of a prestigious external advisory group that I recently formed--the Secretary of Energy Advisory Board.

Today, I would like to begin my testimony by painting the broad picture of future research and development needs that emerges from my personal synthesis of the many suggestions received from various sources. Then, I will lay out what I think are some of the areas where the DOE National Laboratories are rising to the challenges of the future, and some areas where I believe further help is needed from the Congress. I will conclude by describing the status of a high-level study of the National Laboratories that I have set in motion.

II. The Future National Agenda in Research and Development

I firmly believe that, if our Nation can summon the will, we can enjoy an unparalleled decade of advances in research and education in the 1990s. Our scientific instruments and techniques are growing in power and sophistication. Computation and modeling methods are allowing us to understand and simulate systems of unimaginable complexity. Our society is developing a firm consensus on the importance of improving education, and it stands ready to marshal significant resources to the task of reforming the entire educational system. Surely, the problems that confront our society will demand every ounce of scientific and engineering intelligence that we have and every trained pair of hands that we can put to the task.

In the coming decade, I see four forces driving the pace and structure of our National scientific and technical efforts.

- The first of these forces will be the changed geopolitical realities of the 1990s. The bipolar world of the postwar superpowers is being replaced by a multipolar world. Our national defense research and development structure needs to adapt to the new demands of this multipolar world.

- The second dominant force that will shape research and development in the 1990s is a heightened concern for the environment, concomitant with a renewed interest in energy efficiency and conservation.

- The third force is a greater focus in society on the need to improve education--especially science and engineering education--at all levels.

- Finally, I believe that government-funded research and development in the 1990s will be driven by a strong emphasis on sustaining and improving U.S. economic competitiveness in an increasingly global and free marketplace.

These driving forces are challenges to our present mode of organizing and supporting fundamental research and development. R&D-intensive agencies such as the Department of Energy must take an entirely new look at their R&D missions and strategies and adapt to new times.

The National Energy Strategy process is a prime vehicle for DOE's exploration of its appropriate role in the Nation's research agenda for the 1990s. The last decade has been a time of extraordinary change in science. Few individuals in 1980 would have confidently predicted the discovery of "high-temperature" superconductivity, or the revolutionary impact of supercomputing on scientific productivity, or the possibility of mapping and sequencing the human genome. In all these areas, DOE has responded well to new and unexpected scientific challenges. In some other areas, though, the DOE response to new research opportunities and needs has not been as bold or as successful. It is my hope that the development of the National Energy Strategy will lead to a searching reevaluation of DOE's traditional research missions and activities.

In tandem with the development of a National Energy Strategy, our Nation is in the process of hammering out a new consensus on a "national defense strategy." This task is proving even more difficult and arduous. Nonetheless, I think that there are now emerging some elements of the research and development agenda that might flow from a new approach to national defense. For example, in the 1980s, defense-related research and development strongly tilted towards the development and deployment end of the spectrum. In the 1990s we have an opportunity to shift the emphasis back to a number of highly promising fundamental research areas. Some of these, including some of the concepts and advances that have come out of the SDI program, have the potential for profoundly changing the nature of warfare.

III. The Defense Missions of the DOE Laboratories

How do the DOE National Laboratories--and particularly those with a mission in national defense--fit into this picture?

First of all, let me say that much of the credit for the past 45 years of peace in Europe can be attributed to the consistent support of advanced defense technologies at the DOE nuclear weapons laboratories. As we make the transition to the world of the 1990s, the need for a strong defense technology base will remain, but the priorities among research areas related to nuclear weapons will shift. Continued enhancement of safety, security, survivability, and command and control of nuclear weapons must receive greater emphasis. The manufacture of warheads will be increasingly dominated by issues of waste minimization in up-front design, waste management in downstream processing, and other environmental impacts. The coming decade will be dominated, in all likelihood, by negotiated cuts in worldwide nuclear weapons stockpiles. Such a process has to be managed carefully, if we are to preserve our national security and enhance global stability. In such an environment, the competencies at the nuclear weapons laboratories become all the more important, since considerations such as weapons reliability and safety loom larger as the size of the stockpile decreases. Thus, the need for research, development, and testing will remain crucial--and it will not scale down simply with the number of deployed weapons. Maintenance of a competent cadre of nuclear weapons experts is essential if the United States is to have confidence in a nuclear deterrent that will remain a key part of its defense strategy for years to come.

Along with expertise in nuclear weapons design and manufacture, the 1990s will require related expertise that currently is centered at the DOE National Defense Laboratories. These laboratories are the Nation's prime technological resource for arms control, verification technologies, a number of intelligence technologies, and strategic defense technologies. The intellectual strength of the Laboratories in all of these technologies grows out of close interaction between them and a vibrant program of nuclear weapons research, development, and testing. A multipolar world, with fewer superpower nuclear weapons but with a proliferation of third-world weapons, may hold greater possibilities for unpleasant surprises. The DOE nuclear weapons laboratories will continue to have a vital role in anticipating technological developments and in assisting arms control and verification efforts.

We can retain cadre of first-class weapons experts at our National Laboratories through a combination of support for vigorous research programs in the above areas and support for closely related research that meets specific civilian needs. Examples of the latter would include the following.

- Laser science and technology, an area of broad applicability to both military and civilian needs. Current work in the nuclear weapons laboratories encompasses both military-related work on inertial confinement fusion and civilian-related spin-offs to advanced photolithography for computer chip manufacture.

- Advanced computational science and technology, where fundamental work at the nuclear weapons laboratories is finding application both to weapons design and simulation and to other challenges such as the mapping of the human genome.

- Fluid dynamics and three-dimensional hydrodynamics, where research and computer modeling at the weapons laboratories has contributed both to better understanding of weapons-related phenomena and of gaseous mixtures in internal combustion engines.

- Research on high-temperature ceramic materials has benefited defense systems that must operate in environments of extreme temperature and pressure as well as systems for civilian applications that must also endure demanding conditions.

- Geophysics research, drilling technology, and studies of transport of contaminants in subsurface environments are applicable both to the underground testing program as well as to oil and gas recovery.

In areas such as these, maintaining technical excellence at the Laboratories purely for civilian applications can provide the additional benefit of retaining trained personnel as insurance against unforeseen future shifts in international relations.

IV. Civilian Missions of the DOE Laboratories

Beyond defense missions, I believe that all DOE National Laboratories have important contributions to make to our national well-being in the 1990s. DOE scientists and engineers have an impressive track record for excellence in innovation. The DOE laboratories are star performers in the R&D-100 Awards--an international competition that Research and Development magazine conducts each year to identify the 100 new products, processes, and materials deemed most significant from a technical perspective. Over the past 27 years, DOE laboratories and facilities have won more than 275 R&D-100 Awards. This year, more than a quarter of the 100 awards will be made to DOE-developed technologies.

What does this mean to American economic competitiveness? Since 1963, forty-five percent of DOE's award-winning technologies have been commercialized.

Some 29 companies have been formed in the process of commercialization, and laboratory employees were directly involved in establishing 76 percent of them. This is only a part of the larger universe of spin-off companies that started with DOE-developed technologies. Over 140 spin-off companies based on technologies developed by DOE have been formed since 1985. In Fiscal Year 1988, some 35 new companies were reported, in fields ranging from in-situ vitrification of waste to process design technologies for the biochemical industry. I am proud of DOE's track record of developing technologies that have created new jobs and wealth in the United States.

During the past year, I have traveled to several of our major laboratories, including the three nuclear weapons laboratories (Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratory), as well as the Oak Ridge National Laboratory in Tennessee and Argonne National Laboratory in Illinois. I have seen at first hand the incredible scientific and technical capabilities of our National Laboratory researchers. These visits have reinforced my commitment to see that the benefits of DOE-sponsored research are realized even more effectively by the U.S. economy. Unless the results of our research are productively used by U.S. industry and the consumer, we are wasting the taxpayer's investment in that research. Accordingly, I have given high priority at the Department of Energy to developing strategies to promote technology transfer to even greater degrees.

A key help in this regard has been the National Competitiveness Technology Transfer Act of 1989. This Act made technology transfer a mission of all DOE laboratories, and provided a new mechanism for laboratory-industry cooperation--the cooperative research and development agreements (CRADAs). The DOE is moving aggressively to implement the Act. We have mobilized over 100 people in the Department and its laboratories to develop a program that will provide a fast, flexible, and predictable environment for technology transfer from our laboratories.

I have also been working to make sure that industry becomes better informed about the capabilities of our Laboratories. For example, last March I hosted a Technology Transfer Round Table in Washington with the Secretary of Commerce and Senators Domenici and Bingaman. Twenty-four participants from government and industry discussed the technology transfer process and attempted to identify barriers and options for improving industry/government interactions. Some of the keys to success that this group helped to identify were:

- The importance of "market pull" to the success of technology transfer. The agency and its laboratories need a better understanding of what U.S. industry can use and commercialize.

- The importance of obtaining intellectual property rights, through patents and licensing, for the successful commercialization of technology by private companies.

- The need for flexibility in working with a variety of different industries and companies.

- The need to examine alternatives for "closing the gap" between where Federal research leaves off and industry research and development picks up.

- The need to streamline our administrative processes to make it easier for industry to work with the Federal sector.

The Department of Energy is carefully studying these requirements for successful technology transfer, as well as lessons learned from our experiences to date in expanding our efforts at technology transfer. Among our successes are the High-Temperature Superconductivity Pilot Centers. Three such centers were launched in late 1988 at Los Alamos National Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory. In these pilot centers, DOE is using short, standardized contracts and timely field office approval of collaborative agreements with the private sector. This approach is paying off. In the first year, 24 agreements were signed between industry and the High-Temperature Superconductivity Pilot Centers, with 50 percent cost-sharing. Over 40 companies and universities participated in this pilot effort.

This past week, DOE took some concrete steps to further improve the access of industry to state-of-the-art technology developed in our National Laboratories. We signed two agreements, one with a consortium of specialty metals industries and the other with a consortium of advanced manufacturing industries, to provide them with technology developed in the defense programs of the Department of Energy. Under both agreements, member companies will be able to work directly with our laboratories' best engineers and scientists.

They will also be able to use some of the world's most sophisticated equipment to advance the state of the art in their respective manufacturing technologies. From DOE's perspective, the National Laboratories will gain insights into the technologies and techniques used by industry. This success in finding ways to extract technology of commercial value from the weapons complex, and placing that technology in the hands of American industry, represents another important facet of DOE's overall program of facilitating technology transfer from its laboratories and production facilities.

The Department of Energy has also taken a strong leading role in the development of programs to improve science and mathematics education in the United States. Last year, the President and the Nation's Governors adopted six forward-looking and challenging goals, one of which is excellence in mathematics and science education. The National Laboratories are uniquely positioned to help the United States reach this objective, and their help could not be more timely.

One of the most serious problems facing the Nation over the next ten years is the declining number of young Americans--including women, minorities, and the disabled--who are interested in pursuing careers in science and engineering. Those who *are* interested often receive inadequate preparation for such careers. This situation represents a crisis in science education that has serious implications for our Nation's continued economic and technological competitiveness. It also has implications for the Department of Energy, which requires a well-trained, highly motivated work force of scientists and engineers, if it is to meet its current and future challenges.

On May 21, 1990, I issued a Secretary of Energy Notice establishing education as a primary Departmental mission and encouraging education outreach efforts on the part of all DOE and contract personnel. This Notice culminated a year of important changes in the Department's education programs. The blueprint for many of those changes was provided by the Math/Science Education Action Conference held at the Lawrence Hall of Science in Berkeley, California last October, just ten days after the President's historic Education Summit with the Nation's Governors. The two-day Berkeley conference brought together over 250 scientists, educators, policy makers, and industry representatives, including representatives from the White House, the Congress, the National Science Foundation, NASA, and the Departments of Education, Interior, Defense, Health and Human Services, and Labor. The report of the Berkeley Conference was released by the DOE on May 22, 1990, and copies have been provided to this Subcommittee. The report lays out a plan of action for the Department and its National Laboratories, in partnership with other Federal agencies, States, schools, and private sector organizations.

The National Laboratories have traditionally had education as one of their missions, but the historic focus of their efforts has been at the undergraduate, graduate and postdoctoral level. Based on the recommendations of the Berkeley Conference, the Department has begun a significant expansion of support for precollege science education programs at the National Laboratories, including programs specifically designed for precollege math and science teachers. Two core programs are the High School Honors Research Program and the Teacher Research Associate Program, which are two- and eight-week programs, respectively, of on-site participation in research at a National Laboratory.

As a direct outgrowth of the Berkeley Conference, special emphasis has been placed for FY 1991 on the further development of partnerships between DOE laboratories and inner-city and rural schools, with a goal of revitalizing math and science education. New laboratory initiatives include:

- The Bay Area Science and Technology Education Collaboration (BASTEC), in which four National Laboratories in the California Bay Area (Lawrence Berkeley, Lawrence Livermore, Sandia-Livermore, and Stanford Linear Accelerator Laboratories) have joined the private sector to sponsor enrichment programs for all 2,700 teachers in the Oakland Unified School District.

- "The New Explorers Program" involving the Chicago Public Schools, Argonne and Fermi National Laboratories, and ten other Chicago institutions involved in science education, which has reached over 15,000 students already this year;

- Tomorrow I will help inaugurate the Academy for Mathematics and Science Teachers in Chicago, begun by Leon Lederman, former Director of Fermilab, and supported by DOE, the State of Illinois, the City of Chicago, and the private sector.

- The OPTIONS Program at Pacific Northwest Laboratory that will reach thousands of Hispanic, black, and Native American students in the States of Washington and Oregon; and

- A partnership involving Los Alamos and Sandia National Laboratories, middle schools in New Mexico, and Native American schools in northern New Mexico and Arizona.

This latter partnership was formalized this morning by a Memorandum of Understanding (MOU) that I signed with Secretary of the Interior Manuel Lujan, Jr. The MOU provides for a continuing relationship between DOE's Los Alamos and Sandia National Laboratories and the Indian Nation Schools operated by the Bureau of Indian Affairs.

Laboratory involvement in science education will also be spurred in the future with the implementation by DOE technology program offices of my Secretary of Energy Notice on the educational mission of the Department. For example, the Office of Environmental Restoration and Waste Management is already working with the academic community and the National Laboratories to develop a major educational initiative to encourage more young people to consider technical careers in environmental remediation.

Another important role played by the laboratories is to form consortia with minority universities. The Science Consortium, the Science and Technology Alliance, and the Science and Engineering Alliance, for example, are comprised of Lawrence Berkeley, Lawrence Livermore, Sandia, Los Alamos and Oak Ridge National Laboratories, in collaboration with the Ana G. Mendez Foundation colleges in Puerto Rico and New Mexico Highlands University, both Hispanic institutions, and five Historically Black Colleges and Universities: Jackson State, North Carolina A&T, Prairie View A&M, Alabama A&M, and Southern University. These partnerships will increase the research potential of the educational institutions through faculty enhancement at the labs, research funding, and instrumentation programs.

The strides that the Department of Energy has made in the past year to expand its already significant educational base would not have been possible without the excellent foundation of science education programs underway for many years at the National Laboratories. It is not just a matter of adding new dollars. Each dollar spent on a teacher or student at the laboratories is highly leveraged. The facilities, the equipment, and the scientists are already there. Our approach is to use the immense resources at our fingertips more creatively and effectively--in partnership with other Federal agencies, the States, and the private sector--to achieve the National Education Goals.

V. Research and Development on Environmental Restoration and Waste Management

The Department of Energy's accomplishments to date in promoting technology transfer and education provide a foundation for the enhanced efforts I see DOE making in the coming years to promote research and development on environmental restoration and waste management. Our Nation is facing a crisis in this area--not only within the DOE defense production complex, but in thousands of landfills and other sites where wastes have been dumped or abandoned. Our efforts to address this national problem have been hampered by a lack of fundamental understanding of subsurface environments, a paucity of clean-up technologies, and a shortage of trained personnel both to perform the needed research and development and to carry out remediation activities.

I believe that, over the next 20 to 30 years, the field of environmental restoration and waste management will be one of the major growth areas for scientific and technical employment in the United States. We need a new vision and a new set of programs to bring to this field the best talents of universities, industry, and our National Laboratories. And we must do so in a way that maximizes useful partnerships among these three sectors. Each has a special contribution to make. Universities are needed to train a new generation of remediation specialists, an undertaking that will require (1) multidisciplinary approaches to research and training and (2) a determined effort to attract into science and technology segments of our population who are currently underrepresented in such fields. Our National Laboratories can contribute to research and development using DOE sites and facilities as test-beds for environmental restoration. Beyond their general role in such research, the nuclear weapons laboratories have a special role to play in waste minimization research for defense production activities. Industry is the ultimate beneficiary of new knowledge and trained personnel, as well as the major implementor of remediation activities. It must be fully integrated into the research and training activities that occur in academia and federal laboratories. Senator Sam Nunn has recently proposed augmenting the mission of the DOE National Laboratories in environmental research and development. I agree with him on the need to turn our best scientists loose on the environmental challenges that face us, and I have asked my staff to study his proposals carefully.

VI. Secretary of Energy Advisory Board Study of the National Laboratories

In education and technology transfer, then, the Department of Energy's National Laboratories are already rising to the challenges of the 1990s. With appropriate support from the Congress for the President's requested budgets, I believe that the National Laboratories will prove equal to the changing defense requirements of the next decade as well. Why, then, have I commissioned an overall review of the management of the National Laboratory complex from the Secretary of Energy Advisory Board?

My answer is that, to meet the challenges of a rapidly changing world in an effective manner, it is not enough to revitalize, expand, or redirect individual facets of the National Laboratory system. From time to time, it is necessary to step back and take a fresh look at the principles guiding the management of the Laboratory complex, and to ask whether a different approach would better sustain the Laboratories' excellence into the future.

With this goal in mind, I asked a subgroup of the Secretary of Energy Advisory Board to develop a tasking statement for such a study, drawing on their unique perspectives and expertise in research management. This subgroup of SEAB is chaired by Dr. Edward A. Frieman (Director of the Scripps Institute of Oceanography), and includes Dr. Lew Allen, Jr. (Director, Jet Propulsion Laboratory), Dr. Leon M. Lederman (Director Emeritus, Fermi National Accelerator Laboratory), Dr. Hans Mark (Chancellor, University of Texas System), Dr. Michael May (Director Emeritus, Lawrence Livermore National Laboratory), and Dr. John P. McTague (Vice President, Technical Affairs, Ford Motor Company). The group has been working hard at this task over the past several weeks, and I expect to have their proposal for the scope and organization of a study before the end of the summer. Once I review, modify, and approve the charge to the panel, I hope to set the study up quickly and have a preliminary report from the panel within six months of its formation.

Since this distinguished group of individuals are busy trying to formulate advice to me on the most effective scope of this study, I don't want to preempt their deliberations by ruling particular questions in or out of the study this morning. But I would like to place before you some issues that I believe should be on their minds as they put together a draft charge for my review and approval.

- Where are the current and likely future strengths of the National Laboratories? What set of missions would they be best suited to in the 1990s?

- How are relationships and partnerships among performers of research, or between performers and users of research, likely to change in the coming decade? What can DOE do to facilitate closer interactions between laboratory researchers and researchers at universities or in industry?

- As the research missions of the National Laboratories evolve to meet the challenges of the 1990s, and perhaps grow more diverse, how should the management of the laboratories by DOE evolve?

I believe that these are only a few of the many challenging questions that confront the National Laboratories. I hope that my comments here this morning have served to crystallize for you some of my overall views about the accomplishments of the National Laboratories, as well as some of the opportunities that lie before them. I welcome your suggestions of issues that you believe I and the planning group for this study should consider as we finalize the scope of the activity and move forward with its execution.

Thank you very much.

The CHAIRMAN. Thank you very much, Admiral Watkins.

Now, the labs have an unusual modus operandi, or capability, in that they are able to go all the way from R&D to final development in the case of the weapon. They can design a new bomb and take it all the way from the R&D to having a working model and going on and testing it.

I know that is unusual. Is that a unique capability?

Secretary WATKINS. That is a unique capability. It is very unusual for a national laboratory—say, the weapons laboratories—to have a product at the end of the line, and this is why the three in particular are so important to the transfer of technology initiative, because they understand how to move technology from basic research into application, and that is an unusual capability in those laboratories. It is not present elsewhere. So that gives them a leg-up, you might say, in understanding how the transitional process must work.

In fact, some of the best recommendations are coming in from the three lab directors you are going to have before you this morning on how to facilitate that transfer, as to identification of what might be used in the private sector—let us say, ceramic engines. Had we been on the ball years ago, we might have moved ceramic engines into our own commercialization of technology far sooner than we did, because we were worried about the classification transfer.

The CHAIRMAN. Well, the question involved, or one of the questions involved here, is where this research, whatever it is, should be done, and a further question should be whether this capability of the national lab to go all the way from R&D to final product is useful or appropriate, or best in private industry.

Secretary WATKINS. I think it is best in private industry. I do not think anything we are trying to do here is to indicate that our national laboratories are going to be product generators. That is not the idea. It is the experience in those unique laboratories of going to a product that gives them a unique insight on what has to be done to facilitate the transfer of technologies to the private sector.

They understand what that production process is and when you have to bring in those that produce things, early in the research process, who can identify those things which are probably going to be jewels in the private sector as well, such as we did with the SDI transfer of technology. Those are the kinds of experienced people that are in those three weapons laboratories that make them rather unique to help us out here, but we are not asking to build products. We believe that should be in the private sector and continue there.

The CHAIRMAN. I think it is controversial to talk about industrial policy, and it is controversial to talk about being in competition with private industry, but I think it is also a tremendous capability, and I for one am not at all afraid—if it is a great capability and we can use that capability of the labs I think we ought to do it.

For example, if we could develop a High Definition Television (HDTV) machine through the labs, I would not be at all afraid to do it. I would expect that that would probably be beyond the capability of—certainly beyond the present capability of the labs, but I think it is one of those questions we are going to have to face as we determine the new mission of the labs. That is, how far they go in terms of product development.

It seems to me the really big questions are, how do you nominate the research? How do you focus what they do? How do they interface with private industry?

Now I see here that in the first year, 24 agreements were signed between industry and high-temperature superconductivity pilot centers, with 50 percent cost-sharing. Now that sounds like a very good idea. I like the 50 percent cost-sharing, and superconductivity is a perfect thing to do, but how do we decide among the myriad of things that these labs can do in the future, which things they do? I mean you have got a hundred different nominations that come in, let us say, from private industry, how do you choose those? Is there a focus?

I would assume at some point or another we are going to have to decide, well, the labs are going to do these things, and not do these things, all of which is basic research and all of which is good.

And then the next question is, how does Congress figure into this? Do you want to bring to Congress a plan for us to approve? Or should we approve a general process and let the labs approve? Have you thought that through?

Secretary WATKINS. We have thought a lot about it. And we have held hearings on it in developing the National Energy Strategy because the commercialization of technology will be a key element of the strategy. So we have had hearings, we have had documentation, we have had some of these lab directors here this morning who have done some superb work in this area.

The superconductivity centers of excellence that we have, the three of them, are basically a template for what we can do. How we control it, how we watch the discretionary funding that the lab directors should have to do individual research, and the various kinds of things that could lead us to better answers, all of that will be very important.

I think there are critical technologies that definitely need focus, we can identify those. Those are fairly well known out there; also those that are marketable. The industry coming before our hearings has said you have got to understand that market pull has to be part of the transfer of technology regime. You have to understand that.

And this is why industry's involvement very early in the process is critical to us. We have to set up mechanisms at these weapons labs to allow access to the information that would be basically unclassified. I think we can do all these things, but we have not really set up that institutional process as well as we would like. But it is being built, and DOE headquarters has set up technology transfer entities, as have the laboratories that you will be hearing from this morning.

So we are starting to move. I think by the end of this year, by the time we really carry out the transfer of the technology act of last year, which I hope to have well underway over the next 6 months, that is when I think we will have to get back with you up here on the Hill to let you know how we are managing this and how we would make those distinctions.

The CHAIRMAN. Well, I happen to Chair, as you know, the Energy and Water Development Appropriations Subcommittee that funds the national labs. Senators Domenici, McClure, and Bumpers are members of that subcommittee. So we sort of control both ends, or we influence, to some extent both ends.

I am wondering in my own mind whether we ought to try to have a new charter, or a new defined process, by which the new labs will pick and choose among technologies and that sort of thing. Or whether we ought to experiment for a while before we try to fix that into law?

Secretary WATKINS. I would like to be challenged by you, Mr. Chairman, to come back here after the first of the year with a proposal of how we might want to move into an expansion of last year's act, and put on the next increment as an amendment, if you will. Because I do think that we have to work this out. We are going to need some help, probably, in clearing up ethical problems associated with transfer of technology, when it comes to human beings.

We have a situation where we would like very much to have technologists in industry come and share with us, and then move back into industry again without fear of going to jail. These things are very important.

We need to have all of this aired. You may decide that there is some efficacy in giving us a special waiver, if you will, for certain technologies that you agree with up here, and we can talk about how we would do this, and how we would control conflict of interest under those special circumstances. We need to do this to show whether or not we can move this Nation faster than other nations offshore are now doing to beat us at our own technology commercialization.

So we are going to need that, but we are not ready to ask you in specific yet. We will be, I think, by the end of this year or by early next year. So I would like to be given that kind of a task by you, because definitely we have to work with you all to make this come to fruition.

The CHAIRMAN. Well, clearly, superconductivity is something you ought to be doing. And clearly, at least in development of technology for environmental cleanup is something that you ought to be pursuing. Beyond that, I think there are a lot of things that you could very well be doing. And there will be highly controversial issues to resolve such as how we decide who ought to conduct certain research, how technology is transferred, how much input is there from the private sector. There will be claims of industrial policy. There will be claims of the government trying to pick winners and losers. There will be all of that.

In my opinion, I think we do much too little in terms of science R&D in this country. I think this could be an historic breakthrough for the country to use the tremendous resources of these labs. But we are going to have to go into it with our eyes wide open. It could be revolutionary, but not this year. This year we will step carefully and innovate as we go along. I think we ought to probably do that before we try to formalize this new relationship and the new process.

Secretary WATKINS. I agree, Mr. Chairman.

I think we are learning a great deal right now. We are finding that some of these mythical barriers really are not barriers. We can solve them by negotiations with the private entities now working in superconductivity pilot centers, for example. We know that these kinds of things work. There is a receptivity out there, but there is also a caution. We have got to worry about patent rights and intellectual property rights. We have to worry about a lot of things. But I do not think we should just stand around and worry; let us sit down and talk about it and negotiate it.

The CHAIRMAN. Well, we probably better get those things like patent rights and all that set early on.

Secretary WATKINS. Yes, sir.

The CHAIRMAN. That is one thing we cannot put off.

Well, I have talked too long. If I may, let me turn the questioning now, if we may stay on this side with the Subcommittee Chairman, and let me call on Senator Ford.

Senator FORD. Thank you, Mr. Chairman.

Admiral, in developing questions for you today, I had some things on my mind which I laid out in my opening statement, and then questions that I developed when we received your statement this morning. You have answered a great many of those, which is normal. And I appreciate that.

So I am going to ask you a couple of questions, and then maybe submit some to you to answer in writing. On page 3 in the second paragraph, you said that no single laboratory or group of laboratories anywhere in the country can compare with this resource. How do we compare with labs in offshore countries? Are we as good or better, or are we falling behind?

Secretary WATKINS. The science in our laboratories is the finest in the world, Senator Ford.

Senator FORD. I like that word.

Secretary WATKINS. The problem is, the move to application of some of the basic research runs into a labyrinth of laws, of ethical considerations and so forth, that are much more stringent than we find elsewhere in the world. We simply do not seem to be able to move from a fundamental technology evolution out of our laboratories into application as fast as other nations.

I think those are the kinds of things we have to go after in a very special way, at least in the areas of some critical technologies that are very important to the economic underpinnings of the Nation, such as superconductivity, which we have addressed, as a specific, critical technology area.

Senator FORD. I guess that answers somewhat the problem out there, we do the research and we develop it, but we never get it into the marketplace.

Secretary WATKINS. No, we sell the technology cheap, and we do not take advantage of the 100 or more to 1 leverage that you get out of taking it to application faster than our competitors. This is at the hub of the whole effort by the President to establish his Counsel on Competitiveness under the Vice President, of which I am a member. We are aggressively going after things like biotechnology, another critical technology.

We do work in biotechnology at DOE, a lot of it, such as biomass. We are in the middle, as you know, of the human genome mapping business with the National Institute of Health. This is a very, very critical technology, I think, for the long haul. It is one of the longer term objectives. But all of these things are very important. When we make some breakthroughs, we should be able to move it with "Made in the USA" on it, before we see these big signs, made everywhere else in the world, with our own technology. That is what we are really talking about here.

Senator **Ford**. Well, I think Senator Johnston's point about the patents and so forth needs to be an early-on situation, you need to get after that so that we can be in a position to get the leverage that you talk about.

Secretary **Watkins**. You need to ask our three lab directors here—Dr. Narath, for example, at Sandia National Laboratory, has gone from the laboratory to AT&T and back to the laboratory. He has an invaluable background as a director. He has seen all this, and he can answer some of your questions about how we might be able to—in fact all the directors can—how we might be able to facilitate these things. We are not ready to ask you for legislative change yet, or even regulatory change, or other changes, but we are on the verge of being able to identify these very significant barriers to facilitating the transfer of basic research into application.

Senator **Ford**. I think we ought to tear the barriers down as fast as we can. And I think tomorrow would not be too soon, if you could get it done, in my opinion.

In the technology transfer, you make a statement about the R&D 100 Awards, an international competition that Research and Development Magazine conducts each year to identify the 100 new products, processes and materials deemed most significant from a technical perspective. You say over the last 27 years the DOE labs and facilities have won 275 R&D 100 Awards.

Now what does that mean? We do the research and that is it, and then we sell it to somebody else cheap? We won all these awards and proved that we are good, but then does that ultimately go someplace else?

Secretary **Watkins**. Well, in those particular cases I think what we are seeing is our laboratories represent about 3 percent of the total scientific intellectual potential we have in the Nation.

Senator **Ford**. 3 percent?

Secretary **Watkins**. 3 percent. What you are talking about here is generating awards for something around 10 percent of the exciting new technologies that have a high likelihood of moving in a very productive way into society.

So I think from that, that tells you that we have a very unique and competitive mentality out there in our national laboratories that really is doing a job for the Nation and giving us the prestige that we all seek.

So I think that is why those numbers are important. Most of those technologies, at least in the old days, used to go into American commercialization, but somehow we have been outrun in recent years.

Senator **Ford**. You also say in the next sentence over 140 spinoff companies based on technologies developed by DOE have been formed in the last 5 years.

Now how did they do that? How did they get 140 companies spun off from your research? Did they have the patents?

Secretary **Watkins**. I cannot answer that, Senator Ford. I would have to defer to my directors to give you some examples and specifics on that. I just do not have that.

Senator **Ford**. Of course, as you say, this created new jobs. It also created new wealth. I was just wondering how that worked because that sounds like a good number from 3 percent of the research, and it does create new jobs. I would like to know how you worked that out, how they got the patents if there were patents. What kind of interest was displayed, or was this a private effort?

Secretary **Watkins**. I will supply that for the record, Senator Ford. I will be glad to list those 140, and we will talk a little about——

Senator **Ford**. I do not think you have to list them all. I think you can just kind of give me a ballpark feel for it.

One of the things I would like to know is of these 140 companies that were spun off, how much of that was private and public funds in a coordinated effort to develop what we finally spun off?

Secretary **Watkins**. I will provide that answer for the record, Senator Ford.

[The information referred to follows:]

TECHNOLOGY TRANSFER

In recent years, the Department has made a concerted effort to encourage and facilitate the spinoff of technology in its laboratories to the private sector. The laboratory contractors can now elect to take title to inventions automatically in most cases. In defense-related programs and other sensitive areas, in the interest of national security, the requests to elect to title are reviewed on a case-by-case basis. All laboratory operating contractors can now copyright software and license it. As a result of these changes, it is easier for new companies to be formed using laboratory licensed technology. In a recent survey of R&D 100 Awards received by the Department, it was determined that approximately 45% of the DOE award winning technologies have been commercialized. Some 29 newly formed companies have been based on the technologies, and laboratory employees were directly involved in establishing 76 percent of them. Some laboratories allow researchers to leave the laboratory to start up companies while retaining rights to rejoin the laboratory should the company fail. Most of the 140 companies based on DOE laboratories technology, formed over the past five years, do not involve a patented technology.

Comprehensive data on private sector funds invested in these companies cannot be calculated since the Department does not have access to private financial information. In FY 1989, the Department performed $50,000,000 of research and development for private industry on a reimbursable basis. Cooperative projects during that period totaled approximately $36,000,000, with industry and DOE contributing about $18,000,000. The Department's direct programmatic funding for technology transfer activities in FY 1989 was $12,000,000.

The companies formed in 1989 are as follows:

Company Name	Process on Which Company is Based
Carl Pfeiffer Clinic	Spectroscopic/chemical analysis
Illinois Superconductor Corp.	High Temperature Superconductivity
W.R. Cowell Consulting, Inc.	Computer Science
Vernix Research Corp.	Software for coal applications
American Scientific Instrument Co.	Printed circuit boards
Aster Technology	Microelectronics
Theta Technology	Engineering
Electronic Systems Unlimited	Electronic Circuit Design
Biochemical Technology, Inc.	Environmental Monitors
B-Tec	Africanized Bee Detector

Contemporary Applications of Technology	Radon Removal
Microwave Materials Technology	Materials Processing
Codes and Vessels	Pressure Vessels Design
Pellissippi Development Corp.	Environmental Engineering
TechAlliance	Editor for computer software
Reemay	Geotile Fabric
Haz Answers	Waste Management Handling Consultants
INTK Corporation	Annular Centrifugal Contractor
Vista Controls Systems	Process Control Software
Galaxy Computers	Computer Security Technology
Cell Robotica	Laser-based micro manipular for biological cells
Silchemy	Polysilanes
Ames Specialty Metals, new division of Edge Technologies, Inc.	Thermite Reduction process for making permanent magnet materials
M-V Systems	Amorphous silicon production system
QuantiPhy, Inc.	Algal pigments for medical diagnostics industry
Sea-Ag, Inc.	Shellfish aquaculture
Nioptics, Inc.	Nonimaging optics
Augustyn and Company, Inc.	Radiometer Calibration

Senator FORD. One thing also bothers me, Admiral. We spend a substantial amount of money annually for laboratory programs. My figure of $5 billion I guess would be a round number. We are getting into a budget crunch. We are summiteers around here now and not musketeers.

Can all that spending be justified in light of the tightening Federal budget and the deficits we are facing?

Secretary WATKINS. I think the answer is yes, Senator Ford, it can. I really believe that one of the worst things we can do in a situation like this is to mortgage the future. The excitement in this country is in the brains of our scientists and engineers.

The only problem we have in not returning those moneys to ourself is in this transfer of technology issue. So what we are talking about here is insuring that we have a system set into place that gets those economics back in our favor; that is, the dollars flowing back into the American treasury on a "Made in the USA" basis. I believe that by doing that we are going to get the moneys needed to continue this research. So I think if we pare down the research, what is going to happen is it will be a self-defeating sort of approach.

I would like to think at this particular time, with peace breaking out in the world, so to speak, and without the threat of global conflict, that perhaps this is the time to strengthen research.

Senator FORD. Do you have any idea how much private money is paid into the laboratories in addition to the $5 billion?

Secretary WATKINS. We do have a small amount of work for others where we are not in competition with the private sector, but it is relatively small. Most of our work comes from DOE and Department of Defense (DOD) work for others. We do have some others, but we have to be very careful because we are not in competition with the private sector.

Senator FORD. This is my last question. You mentioned DOD, and Senator Nunn has proposed, I think several weeks ago—and maybe my colleagues know more about that than I—the formation of a Strategic Environmental Research Program. I think that is what he has called it. This program, developed by the Department of Defense, is intended to focus the resources of the defense establishment on environmental issues.

What does this program mean to the national laboratories? Are we going to be a part of that? How do we look at that?

Secretary WATKINS. Well, this is one area in which I have been discussing many of my ideas with Senator Nunn. I think it is a very good concept. My problem is right now I do not think it is well enough defined to be really helpful at this point, and we are trying to work with his staff and working with the Energy and Natural Resources staff here——

Senator FORD. Is he getting money out of the defense budget?

Secretary WATKINS. Yes, sir. What happened is the transition of dollars took place, let us say $300 million, from more or less the defense side of things which was in a variety of forms, Research, Development Test and Engineering (RDT&E) at our laboratories, special directed weapons, X-ray lasers and so forth. He took it out of that and gave it to this concept that is not that well flushed out at this point.

All I would say is that we need to work very closely with Senator Nunn, the Senate Armed Services Committee and this Committee to make sure that what we are doing is not robbing Peter to pay Paul in some cases.

For example, if you denude RDT&E from our weapons laboratories thinking that we are not going to build better bombs, inside those accounts there will be some very important things for nuclear safety, for testing, for verification strategies, a whole host of things, and we have to be very cautious that we do not think that we are helping the environment when in fact we may be taking out plant and capital dollars at Savannah River in the very area of environment, safety and health that I am trying to put into play.

So a superficial movement from one budget line to another can be very damaging, and I would just like to stay close with the Senate up as we go through this. We have some ideas. We believe there are some very significant problems in the current concept, but we have some ideas that I think would be very beneficial to enhance the laboratories' involvement in waste management, waste minimization and environmental restoration, which I think is a very serious void in the way we manage our national laboratories, not just the weapons labs but all 15 of our national laboratories.

Senator FORD. Admiral, we deal a lot around here with the superficial, transfers and things of that nature, so we are used to that.

Thank you, Mr. Chairman.

Thank you, Admiral.

The CHAIRMAN. Thank you, Senator Ford.

Senator McClure.

Senator McCLURE. I think Senator Domenici has an appointment in the Budget Committee, and I would be glad to yield to him, if I may.

Senator DOMENICI. Thank you very much, Mr. Chairman.

I might say to the lab directors, two of whom are from New Mexico, that I do intend to return. I am going to run off and do something in the other committee.

Mr. Secretary, let me first say to Senator Ford, when the lab directors testify if you care to spend time today you might ask them about patents. Frankly, the Bingaman-Domenici Technology Transfer and Competition Act of 1989 does provide an adequate mechanism on patents and on proprietary interests and on entering into agreements to keep things secret while products are being developed.

Senator FORD. Since you mentioned me, let me say that I am concerned about the patents that are distributed internationally and which do not inure to our benefit.

I am concerned when we pay for all this and we do the research that what we get is help on Main Street, USA and not distribute it on an international basis, thereby not increasing the job opportunities and the wealth opportunities that come from these fine labs.

Senator DOMENICI. I really believe we have taken care of that, and I think they will tell you that the international issue is not a very serious one; but they can address that. In fact, I think it is prohibited, but you can ask them that.

Mr. Secretary, I do believe you will have to wait for an evolution of assignments on which labs take leads in what. For now, I think their expertise in negotiating with the private sector will be the clue as to whether they have the best thing to offer. If they make the right kind of arrangement with the private sector, I think it will be a pretty good indication that their expertise is appropriately being put into play.

Let me tell you what bothers me. If you look at the basic laboratory funding right now for these national laboratories, it comes from two sources: the RDT&E account, which is part of the nuclear deterrent mission; and basic energy research, which is a straight civilian DOE account. Then they build on top of that when they have contracts with Defense to do something very specific or contracts with DOE to do something very specific. You add it up, and it is an ongoing laboratory.

Now what is happening while you, Mr. Secretary, are urging the lab directors, and they are indeed excited about doing things, that their expertise permits them to do that is not directly related to those basic activities is that we continue to run into problems of whether they are authorized, justified, and who is going to jump down their throats if they do it.

Yet, you know and they know that there are areas where they have tremendous expertise and where the tie to their basic mission is very minimal at best, but the technology and the lining up and joining up with the private sector or academia is real and important. Let us just use your initiative in education as an example.

Unless and until we change the mission, which we are going to try to do—we have a bill going through here that you have suggested to change the mission in that regard—they need flexible money to do that under your auspices and direction.

Might I first ask so that we know, you do support flexible financing of some percent of their budget? We think it should be about 6 percent. We have tried to be helpful in the appropriations bill in that regard. Do you agree with that?

Secretary WATKINS. Yes, sir, I do.

Senator DOMENICI. We hope that we can get that done. We have stated the mission in a way that it will still be under your direction. We need assurance that without tying their hands, you will be responsible if other committees of the Congress make their weight felt, you will be responsible in that you will have some guidelines saying this is an appropriate activity and it does not infringe on some other activity of the government, be it National Aeronautics and Space Administration (NASA) or otherwise.

Secretary WATKINS. Yes, sir. We have already informed the Congress by letter exactly what we would do in that regard. We do believe we have to tighten up on our DOE headquarters, but it is not in any way going to be a constraint on those directors in using their best judgment, as long as the general policy guidelines can be agreed to by you up here on the Hill, our directors and myself.

We can do that and set up the procedures to monitor it well without infringing on the freedom that they should have in doing individual research and research under their sponsorship. So I think that this is very definitely something we need to iron out, and we are doing that now with our laboratory directors.

I do believe your 6 percent is a floor. I would not want to go less than that. We have heard a very impassioned plea at the National Academy of Sciences' meeting recently on this very issue, that what we are doing, and what we have done, is giving big research the dollars and we are starving the individual researchers who have been the real guts of the Nation's economic strength in the past. We have to be very cautious in all our budget cuts not to restrict that ingenuity that is sitting out there waiting to be tapped.

They are the ones who are going to solve some of these very horrendous cost problems we have just in the waste management area alone. So what you are saying is very important.

We are very upset with the House markup. Fortunately, this Committee and the Appropriations Committee were good enough to see the merit in this case of holding research up and restoring the moneys that were taken away, which would have been a serious blow to our laboratories. We would have lost about 600 full time employees (FTEs) alone in the very area that will help the Nation out. So this is not an area we should play with. We are talking about human beings and bright minds here. That is primarily where these dollars would have been going.

So I commend the Congress for seeing the wisdom of restoring that, and I know my directors will feel the same way. Hopefully you will hold that in conference.

Senator DOMENICI. Two other brief questions.

Senator Johnston asked you about moving all the way to producing something, and you said you want the private sector to do that. I do understand nonetheless that you would like the authority to move a technology into an enabling posture; that is, one step beyond the research in the direction of moving toward commercial products. Is that correct?

Secretary WATKINS. Yes, sir, and I would hope that the cost sharing formulas can be worked out so that the private industry begins to pick up at a time when this market pull on the technology is clear. We need to be smarter on market pull. This has not been our bag, so we have to set up a procedure and a process that will have the respect of industry, and they, in turn, have to respect from where we are coming, from basic research.

I think those are the kinds of things now that we are negotiating quite well in some of our superconductivity pilot centers and other kinds of transfer of technology initiatives that are already under way under the good act that was passed last year.

Senator DOMENICI. Have you ever thought of how one would objectively evaluate the efficacy of technology transfer? I have had a thought that perhaps we ought to dream up something like a report card, for lack of a better word, where every couple of years a national institution would produce—and I do not mean it in simple-sounding words—an evaluation of how they have added value to the marketplace in their activities.

Secretary WATKINS. I intend to make that a part of the evaluation regime under the National Energy Strategy under the Transfer of Technology chapter. We will set up that mechanism. We have to have it so that we know what we are really doing. I think it is a very good idea, and it is the kind of thing that I think will spark more competition out there within our laboratories and get some excitement going on the fact that not only are they great researchers but they are also in that 20-percent payoff that you get on very basic science and very basic research; that they feel that they are really a part of society and everybody appreciates that.

So I think it is a very good idea.

Senator DOMENICI. Thank you very much.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much, Senator Domenici.

Senator Bingaman.

Senator BINGAMAN. Does Senator McClure wish to go ahead?

Senator McCLURE. Go ahead.

Senator BINGAMAN. Let me ask a couple of questions. We appreciate your being here.

One of the questions that the Chairman, Senator Johnston, asked was how we decide what to focus on and to what to devote the efforts of the labs. In the last couple of years we have worked to put some mechanisms in place for sorting out what some of the priority areas of technology development are for the country.

Particularly, last year we put a provision in the law to establish a national critical technologies panel that would be under the Office of Science and Technology Policy and would have a representative from your Department and from DOD and from NASA and from NIH and all the agencies. John Tuck, your deputy, is your appointee on that panel, as I understand it. The panel meets for the first time this next week.

The idea there was, of course, that that panel would come up with a list of not more than 30 areas of critical technology development that had defense or nondefense significance for us.

That is not intended to be an exclusive list by any means, but it is intended to help us define areas of priority so that they do not get lost in the shuffle.

I would be interested in your view as to whether that will be a useful way of beginning this sorting out process. As I say, I do not think it would be exclusive and certainly would not indicate all areas that need attention, but it seems to be a way to begin to set those priorities. I would be interested in your views on that.

Secretary WATKINS. Well, we are very much involved in the critical technologies panel. My Under Secretary, backed up by, as a matter of fact, one of our top scientists from Sandia National Laboratories, will be on that panel. It is that important to us because it is very much aligned with what we are talking about here.

It gives us perhaps the baseline after discussion with you on anything that might come out of that particular panel as to whether or not this meets the criteria for the generic areas of technologies that we will allow. This is the kind of flexibility that I hope we can generate, a new facilitation, if you will, in these selected areas; not in every area of technology but in these because they are very special to the Nation's economic strength. I think that is what we are talking about here.

So the critical technologies council that is now being established and is about to meet is very important to us. Now we have a lot of lists of critical technologies. The National Academy has done some work over the years; many people have done the work in this area and know exactly what they are. So I think we probably already can identify 20 that are head-and-shoulders kinds of things that we can get on with in terms of working with you perhaps in the next session of Congress, of going the next mile on the Critical Technologies Transfer Act, if we have to have legislative support for what we want to do.

Senator **BINGAMAN**. Thank you very much. Let me ask one other question, because it is one that I have asked you also in the Armed Services Committee on your appearance there and is one that is very important because it comes under the jurisdiction of this Committee. That is the question of flexibility that you have to make organizational changes you need to make to accomplish the metamorphosis which you are describing for us in the Department of Energy.

I have had that conversation with you, and I have expressed my views to you and to Senator Johnston and others that I think the statutes that we have you operating under now unduly constrain your ability to organize that Department in a logical way, and I would be interested in your commenting on it if you would.

Secretary **WATKINS**. That is a very important part of the whole technology transfer issue, as well as the facilitation of my management of the laboratories in a kind of an integrated way, not to impact on program, but to impact on things like technology transfer, like education, like environmental restoration, environmental remediation, waste management, National Energy Strategy linkage, work for others, FTE's, all of these things are not well organized in the Department of Energy today. In fact, on the defense programs side, I do not have anybody addressing that issue in specific.

The laboratory directors are doing a good job, despite headquarters, if you will. We need to know more about what is going to happen in this tremendous decline in Department of Defense expenditures. If it is a 25-percent reduction over the next 5 years, this impacts on my laboratories in a way that I do not have a handle on. I am not in control of those. Now FTE's begin to migrate out of the laboratories, and it is not under my control, because most of the work for others is Department of Defense. And that represents a good, solid 25 percent of the laboratories' work.

So I just cannot have it going willy-nilly along and expect to keep the intellectual base up. So this is what the Secretary of Energy's Advisory Board and I are going to work on in the next few days in Chicago, to deal with those issues. I have to get management control in headquarters to know what is happening to my full-time equivalent scientists and their support structure out there. And that I need help on.

I envision a whole concept of a double-hat in energy research, where the other hat, not now established, is called science advisor. Under that hat, both in the defense labs and non-defense labs, I have two deputy science advisors that can do the kind of coordination work and can report directly to me, because these are areas that are not programmatic in nature, they are management. I need to have some entity set up to deal with technology transfer, education initiatives in math and science, and many other issues that now have no parent in DOE. They are adrift by themselves.

I will be coming up to you very shortly, I am in the process of putting together a final draft of a directive to build a new concept of science advisor, and then I need help to get that ER science advisor as a person who has not only the scientific credibility, but also the industrial or business credibility. So I can bring on a supercollider; I can also maintain weapons safety attention; I can do all the things I have to do to monitor and manage those laboratories so when you hear from John Nuckolls or Sig Hecker or Al Narath here, they will say, do not let our FTEs go down, because we are dealing with fundamental science here.

Yet, the programs are driving my scientific manning levels, and I am not in the position to manage that in the defense laboratories. I am in the position to manage it much better in the non-defense laboratories, the energy laboratories. They are doing a pretty good job there. But there is too much power in these other three national laboratories that I have got to worry a lot more about. So I will be coming back to you very shortly to show you and the Chairman and Senator Domenici, and other interested members in the Committee what we are doing there.

I do not think it is something that will shock anybody. It is what we ought to be doing anyway. But we need to look at the basic legislative directive that established the DOE to see if we need any help from you on perhaps giving us license to do this. That will also link with the transfer of technology entities being established at Sandia, Lawrence Livermore, and Los Alamos now.

Senator **Bingaman**. Thank you very much.

Mr. Chairman, that is all I have at this point. Thank you.

The **Chairman**. Thank you very much.

Senator McClure.

Senator **McClure**. Mr. Chairman, thank you very much. And thank you, Admiral, for your testimony.

I want to be very brief, because this inquiry can cover from A to Z. Really, it is as broad as that. I am not going to take a lot of time talking about Idaho National Engineering Laboratory (INEL) and its activities, although I am tempted to do so.

I want to focus for just a moment, even though I recognize that this is not really the thrust of the times in which we are now engaged with respect to the role on defense. You discussed that in the prepared testimony, as well as in your oral testimony. But all the questioning has not been in that area. And I wish to go back there for a moment, because I do not want to lose sight of that role of the labs.

During this era of time, while we are much more optimistic about the prospects for peace and for real control of armaments worldwide. And I think we are all optimistic about that right now. What do you envision as the role of the Department, and what will you be called upon in the Department of Energy to do to support the weapons program as outlined by the Department of Defense?

Secretary **Watkins**. Well, it is a very important question and it is a very significant question, in that we cannot neglect our primary function in supporting the national security. In this debate today I do not want to in any way downplay the importance of maintaining not only the dollar flow to maintain the weapons stockpile, but also to make sure we understand that RDT&E and the scientists that are needed to stay in our weapons program are vital functions that cannot be overlooked.

And that will happen if we do not pay attention to this area because of the lack of interest, you might say, in nuclear bombs today, as we see in many of the protests around the country. We cannot lose sight of the fact that we need scientists with a standing in their universities in their post-doctoral work, and we cannot relegate this to the second string. We have to maintain that high intellectual quality because of weapons safety, primarily, and weapons design. We are going to a smaller weapons stockpile. That is good.

But the bad news there is you still need a lot of testing. You still need the best scientists. You still need safety as a paramount concern. This takes technical talent of the first order.

I am worried that, in all our discussion, we do not allow that to deteriorate. Therefore, part of my management regime that I talked to Senator Bingaman about would include a deputy science advisor on the defense program side that will come directly to me on these needs. We need to talk about the strength that could wane from these particular entities in national defense protection, which I think is already starting. We are seeing the signs in some of the actions so far over in the House and even in the Senate Armed Services Committee.

We have to worry a lot about that, because what appears to be bomb-building is maintenance of a technical talent that is absolutely essential for nuclear weapons safety and design, as we get to smaller numbers.

Senator McClure. Well, a number of people assume that as we get weapons controls by treaty and by individual decision, and reduce numbers of weapons and systems for delivery of those nuclear weapons, that all you do is, in effect, keep the stockpile that you have and destroy some of them. That there is no need for any further production.

Secretary Watkins. That is not the case at all, Senator McClure, as you know. And this is the problem. We have to deal with that perception both here on Capitol Hill and in the public domain, because it is a very serious misunderstanding about what really happens in that unusual set of weapons.

Senator McClure. Well, that is the reason I mention it now, because I think that perception is growing in this country that now that peace is breaking out all over, there is nothing that needs to be done with respect to defense procurement, except to limit it or to reduce it.

Secretary Watkins. As a matter of fact, as you get lower in weapons, you probably must test more, and you have to be much more cognizant as you get into weapon design work borne out of new technical analytic techniques that we are developing on safety and so forth, of continually worrying about modernization of that stockpile. That always goes on.

Also, you have weapons being returned because of the tritium issue that have to be modernized. All that has to keep going on, in fact, in bigger numbers in all probability, as you begin to bring weapons back. So we cannot get away from that weapons complex as being an essential element, whether we are building up or building down.

Senator McClure. You used the word modernized. I notice that the Politburo, about 3 weeks ago, made a statement which has been largely unreported in this country and even less noted.

In the midst of the current economic crisis in the Soviet Union, and there is a consensus in this country that is what is driving their policy, it is not because they are good guys, it is because they have got problems, they are making changing.

In the midst of this, the Politburo made a statement that there is still a threat from the West and their weapons modernization program must go on unabated, and they did not cut the funding for their weapons modernization program. What implications does that have for your mission in support of DOD?

Secretary Watkins. It just tells us, Senator McClure, that this area cannot be neglected in the race to the peace dividend. We cannot neglect the nuclear deterrent. It does not happen overnight to go to X thousand weapons from Y thousand. We have to recognize we have to do it in a responsible way, and that requires even more attention by our weapons laboratories on design, on modernization, their attention on safety, and so forth. This is the danger that I mentioned earlier of casual cuts in what might appear to the outsider as being bomb production, when, in fact, what we are talking about are these elements of managing a stockpile that is going to be with us a long time.

Senator McClure. I agree with you, and I appreciate your saying that, and I focus on that for the moment, because I think there is going to be the temptation to take all of those dollars out of the activity and the only contest and debate up here will be, where else do we put them, rather than whether they need to be left there or not, or how much needs to be left there.

That, of course, is driven more by the Armed Services Committee and the decisions they make on defense establishment, the defense posture of this country, but you will have to reflect that. If they make the decisions that are in my view appropriate, then you will have a mission. If they make a different decision, then of course it will change.

Secretary Watkins. We are at that juncture right now, Senator McClure, and I hope that we will continue to work well with you and the Chairman and other members of this Committee in finding a meaningful alternative to the current bill out of Senate Armed Services that can really help us and not allow any unwitting migration of these dollars into the wrong accounts at this point in time. We must maintain it.

I think we can satisfy Senator Nunn we have a solid program. We can work with the Hill and work with this Committee to make sure we come out with something that really does not do damage to the very thing that we are all talking about here now, recognizing we are going down in the number of weapons, and that is good.

But you are absolutely right. I mean, euphoria—we may throw out too many babies with the bath water here again, which we are wont to do under these circumstances, and I think we have to go very cautiously at this time. Wrapped up in that Senate Armed Services markup, the Nunn approach, are some great concepts but they need a tremendous amount of clarifying, and we think we can do that and have something very useful without degrading our weapons stockpile intention.

Senator McClure. I am very much concerned about it. I know you are, too, and I appreciate your comment. It is something this Committee will have to watch and make certain, as we supervise your role, and recognizing you wear two hats—one is in support of the defense mission and the other is in everything else that you do—that we appropriately track what is happening and assist you in shaping your programs to accommodate those changes.

Secretary Watkins. I think we have to go back to that one statement we were talking about earlier on the subject of commonality of technology. I think you will get something from our directors today on this.

When we are in basic research, we cannot tell the difference between basic research for nuclear weapons and basic research for medical purposes. We are in very fundamental science. So often the large majority, and let me say very high percentage in the 1990's, is really all-purpose technology that comes out of our research work.

When that is good technology, it is good for everybody, and because an element is designed to go into a bomb—perhaps perform a certain switching function or something like that—it does not mean that that application is not useful for the civilian world.

So I think we have to be very cautious before we think that somehow research in weapons is totally divorced from research in general. The commonality in research is the thing that is not well understood, and I think that is why we keep getting cuts there, because it appears as though you can direct basic research into one area or another, which you cannot do.

Senator McClure. It may not be understood, but I notice that our industrial competitors around the world have noticed, and they oftentimes complain about the advantages that U.S. businesses have as a result of the dollars we spend on the defense establishment, because there is a spin-off.

There was a great spin-off in the space program, and that continues. There is a tremendous spin-off in the SDI program, and I would invite those who have not been there to go see the display that is just across this building right now, with respect to what that research has produced in new technologies. It is dramatic—absolutely dramatic—and yet a number of people think of SDI solely in terms of its effect upon defense posture and competition.

I want to switch for just a moment with respect to the issue of competition with the private sector, because you are conscious of that. There is some talk about the patent issues.

I remember going through those patent issues back with the Office of Saline Water. That goes back a long time, and we tried to find out how you merge Federal expenditures in research into the opportunities to commercialize the results of that research. That is an on-going debate. It has been going on for all the years I have been here, and yet we seem to have some problems with it.

I think the patent issue is pretty well set, if I understand correctly, and I will want to hear from others if indeed that is not true.

But my belief is that the patent issue is pretty well set. That is not the obstacle.

Just as we share with the Armed Services Committee, or reflect in this committee the actions taken by the Armed Services Committee and the Congress and the Administration on defense policy, there is a lot that deals with competition, the competitiveness of this country.

Some 50, 60, 70 years ago, this country had a great emphasis upon basic research. Our greatest companies over these many years have had large budgets in basic research, and now we have moved almost all of that out of business, partly because MBA programs in all our great universities look at opportunity costs, and there is not much opportunity cost or reward in basic research. That is not where you get the immediate returns on investment, and it is immediate returns that drive the commercial sector in our country far too much today.

But we also do not help in terms of other governmental policy, not just with respect to what happens in labs. We need the Commerce Committee, the Ways and Means Committee, the Finance Committee, the other committees of the Congress, to look at what we do to business to kill their ability to be competitive.

I know that there was a period of time when INEL was prohibited from producing any spin-off businesses. That was an act of Department of Energy policy at that period of time, and I thought it was wrong then. I still think it was wrong, although I do recognize that the moment one of your scientists employed by the Federal Government gets involved in a spin-off business, there is somebody out there saying, hey, that is unfair competition. How do you respond to that?

Secretary **Watkins**. Well, I think you respond to that by first having an institutional process where transfer of technology is a recognized good thing to do for the country, and you set up a process which is open and under the scrutiny of watchful eyes. We think we can do that and avoid that kind of perception.

I think a lot of that perception comes right here from Capitol Hill, by oversight committees and so forth, beating us about the head and shoulders. Now, we have got to find out who are the good guys and the bad guys, and there are very few bad guys, generally, that we have found in the past that have some kind of sinister motive in a transfer.

We know people that have moved with technology and have been very professional in the way they have done it, and they have not capitalized for any personal gain. So I think we have to find the right formula and have it aired well with you, and perhaps given some strength in law. Maybe it has to go for these specified critical technologies which will give us a foot in the door, and just see how many bad guys we have out there.

I think it is a very strong number, and we should go after them as individuals and not try to change the whole system, which we usually want to do to handle a handful of people who do not seem to have the ethical values that they should in this kind of a process.

But we have to find a way to go through that and to demonstrate and to open ourselves up and allow people to look at what people are doing, and not just to assume that they are crooks at the very outset. People have to go with the technology. They really have to, or the transfer is going to be too sluggish.

That means that people who work in our labs many times will have to move with the technology and then come back to the lab, and we should allow that to happen under a strict set of rules that we can work up for that individual for conflict of interest purposes.

Senator McClure. Well, I think we have overreacted to the conflict of interest question over the years. I particularly like your analogy to people that move from government employment to the private sector and back again. Some people call it a revolving door. I think it is a very healthy thing for us in the government to have people in the private sector involved in government. They bring skills and attitudes the government does not enhance, and if they move out from government into the private sector, they can take things with them into the private sector that strengthens the private sector.

I do think you have to have clear roles. You have to want to make certain you do not see unethical behavior creep into that, but I do not fear that nearly as much as I do trying to draw a strict wall of separation that inhibits our ability to use the assets that we have in government broadly, but certainly in these labs particularly, in application to things that will make us better competitors in the world and will bring a better life to the citizens we all try to serve.

Secretary Watkins. I agree.

Senator McClure. I would also make a remark in passing, and I think it is important to make it, as we look at this question of environmental clean-up and environmental technology.

I know as a matter of personal knowledge from a variety of sources, that the private sector is geared up to do far more than government is permitting it to do today. A lot of the activity follows dollars, and EPA has the only dollars that are involved in that at the present time—major dollars—and EPA is simply using it all up in bureaucratic overhead, in my judgment.

I know of a number of commercial activities—engineering firms—that geared up to be involved in the environmental clean-up work, and EPA did not match that with any contracts. The result is, they staffed up, expanded in anticipation of doing something really good, and EPA is sitting on the dollars. There are no contracts being let, except for some that I think are very wasteful, hauling out the dirt in people's front yards and hauling other dirt in at a very high cost.

I could give you a few other examples like that, but they are pathetic, and they are a waste of the taxpayer's money. But it is more government's fault than it is the fault of the private sector. There is more skill, more expertise, more willingness to be involved than is being matched in terms of governmental activity that supports or assists it.

I am not opposed to the labs getting involved in the technology. We need to know something about, how do you deal with chemical compounds? How do you deal with the companies that produce chemical compounds that do not break down naturally in the environment into benign substances? How do we go about treating those substances once they have been released in the environment? How do we get them into a nonthreatening form?

There is a great deal of basic science that needs to be done there. We have not asked chemical companies to develop that science, and I think perhaps we should, although that is not within this committee, but I do believe that our labs can be directed to do some of that work, to deal with the environmental consequences of a technological society in which we look at the front end of the cycle much more than we do at the back end of the cycle.

Secretary WATKINS. I could not agree more, and I think it is very important that this committee show that kind of leadership on the Hill when we see amendments to bills that would take away the environmental restoration and waste management technologies at our national laboratories as being the responsibility of the Department of Energy.

So I would say we are trying to get a clean bill to go through on Environmental Protection Agency (EPA) for raising that to Cabinet level. It has been adorned with a number of amendments which would do damage to the very thing you are talking about, Senator McClure.

We have to keep it clean, because we should not have the regulators being the innovators in the very technologies they have to regulate. We ought to separate that and demand that we produce new technologies and dedicate our laboratories as an integrated entity to really take this thing on and do a good job. We can do that and we desperately need it, not just for our DOE complex but, more importantly, for the Nation as a whole.

Senator MCCLURE. I think it is important for us to remember that it is not just a question of doing, it is also a question of learning how to do. It is not just a question of learning how to do, but it is also a question of doing. I think the juncture between those two sets of activities is very important.

I was pleased to see that you very recently entered into an MOU with the Corps of Engineers with some clean-up work at Hanford. They do have expertise which they can apply, but they cannot and do not possess all of the expertise that is necessary to handle that problem.

I think the way you approached that problem was the correct way, rather than trying to strip you of authority and invest it in some other agency to do the work which you are more capable of directing than someone else who is less technically proficient, in terms of the technology that must be employed.

Secretary WATKINS. We are moving out, Senator McClure. We are not waiting. Our labs are geared up for this now, and we are beginning to build the infrastructure under Mr. Duffy, who I hope will be made an Assistant Secretary, with help of this committee, so that his approach to this, and our laboratories' approach, can be coordinated in Washington by my science advisor as well as Mr. Duffy, directly with our labs, so we have some other kind of entity overseeing the technologies that are so important here.

By the way, I think this is one of the biggest growth industries in the country, and I would hope that we do not end up having offshore nations come over here with their equipment to clean up the United States. I do not think we have to do that. We have a tremendous potential here in the transfer of technology, to get this equipment not only here, but then made available to the lesser developed countries that we are trying to help now, with the explosion of democracy in Eastern Europe, for example.

So we need to bring "Made in the U.S.A." equipment in to start doing these things, and hopefully that will again enhance the economic strength to continue the program, so it is a self-help program, if you will, and this one area is very important. That is why we are talking about this. Not because we are do-gooders in environment in that area, but we feel very strongly that new technologies can cut these costs of remediation down and that new technologies can help us prevent it in the first place.

We are generating waste today that we do not need to generate, and we have not put the talent on that issue to come in up-front, and that is where the labs are at their very best.

Senator **McClure**. Thank you very much.

The **Chairman**. Admiral Watkins, thank you very much. I am delighted that you are making this a high priority. This committee and the Appropriations Subcommittee on Energy and Water Development also consider it to be a very high priority. I look forward to working with you, as well as the directors of the national labs, to get a new mandate, a new charter for the national labs.

We are going to have to find our way as we go, but I very much would like to do that, and I know other members of this Committee would. I think it justifies all the efforts—the excellent efforts—which you and your good staff can put into it, and we will cooperate with you to make it happen.

Secretary **Watkins**. Thank you, and thank you for the lovely gift.

The **Chairman**. Thank you.

Next, we are pleased to welcome three directors of the national labs. I am sorry that I am not going to be present for their testimony. I am called elsewhere, but Sig Hecker, who is Director at Los Alamos, Dr. Albert Narath, who is President of Sandia National Labs, and Dr. John Nuckolls, who is Director of Lawrence Livermore, are here to testify.

Senator **Bingaman** [presiding]. Gentlemen, thank you very much for being here. Why do we not jump right into the testimony? I think the best way to proceed, if we could, is to have each of you summarize your statement. We have, of course, your full statement, and we will include it in the record.

Why do we not start with Dr. Nuckolls and just go across, or did we have a different order agreed to? Oh, it is the other way around. Dr. Hecker, we are pleased to start with you.

STATEMENT OF DR. SIEGFRIED S. HECKER, DIRECTOR, LOS ALAMOS NATIONAL LABORATORY

Dr. **Hecker**. Thank you, Senator Bingaman and Senator McClure, it is my pleasure to be here and to be given the opportunity to talk about the future new directions of the laboratories. Senator Bingaman, you asked me to do that back in November 1987, also. However, that was before the shift in the plate tectonics of world politics and all the resulting changes that have happened so far.

As you know, nuclear weapons still are our primary mission and our statutory responsibility, but we do contribute in a number of other areas. What I have tried to do today is to summarize, to give you a flavor of what we do in these other areas, as well as our basic responsibilities, and I have prepared this rather large statement for you, and I was very much looking forward to reading my 65-page statement for the Committee this morning. However, in view of the time, I had also prepared an oral statement, but I will summarize that as well.

What I would like to do is to walk you through the picture part of my document, and so if you also have a hand-out that shows you copies of viewgraphs, I would just like to briefly walk through that to give you a flavor. What I decided to do for this morning is to translate what we do at the laboratory into issues of public concern, and that is issues such as environmental degradation, energy, economic competitiveness, health care, drugs and terrorism, education, and then of course, the national security defense mission.

If you will refer to the first picture, it is just a brief overview of one of the things that we have done in the environmental arena, and again I will have to walk you through these very quickly in view of the time, but essentially this is an instrument that we call the midget mass spectrometer.

It is a portable unit that one is able to take out into the field to help to characterize waste sites, and as you know, right now, the characterization is an immense part of the entire waste restoration problem, and in fact normally what one does now is, you do an extensive number of field samples, you do careful quality control, you remove, of course, a sample, you take it to a laboratory that is qualified, you do the analysis. All of this typically takes 5 to 6 weeks and about $5,000 per sample. Some of the estimates for current DOE site characterization alone range as high as $1 billion.

So what this unit would be able to do is to go out into the field and essentially make measurements on part of the constituents that are important; the volatile organic compounds such as, let us say, trichloroethylene, and do it in the field, in situ. It could do it in 20 minutes at an overall reduction of cost of approximately 30 percent.

So that is the sort of technology that we have developed that we are currently working with industry to try to get out into the field as quickly as possible. Of course, this will take demonstration; it will take working with EPA in order to get it approved by EPA.

The next couple of pictures give you some idea of a very exciting new discovery, and that is an idea to treat nuclear waste by transmuting that nuclear waste with accelerators. The idea of transmutation of nuclear waste has been around a long time. Typically, people have recommended using neutrons from reactors or neutrons from accelerators, but using the neutrons from accelerators has not been very practical in the past.

On the basis of the work that we have done on the neutral particle beam program for SDI, we have brought the art of high-energy, high-current accelerators to the point where we now think that it may be practical, and at least it is a germ of the right idea, to transmute the nuclear waste after appropriate chemical separation to the point where one would have to contain that nuclear waste for perhaps only hundreds of years instead of the 10,000 to hundreds of thousands of years.

So I caution you that it is still an idea, but there are a couple of breakthroughs that have been made in the last few months at our laboratory that I think make this idea worth pursuing.

The next area is one that was discussed much this morning, that of economic competitiveness. Certainly that needs no introduction to this panel since, Senator Bingaman, you and Senator Domenici are the authors of the National Competitiveness Technology Transfer Act.

In the text I describe what I call a new paradigm for technology transfer. That is one of strategic alliances between the laboratories and industry, strategic alliances on technologies that are crucial to this country's future both from a defense as well as from a civilian standpoint, technologies such as supercomputers, superconductors, semiconductors, et cetera.

I am sorry. I have actually gotten a bit out of sequence. I will skip the energy-related activities where I show you some short-term activities that we have taken in oil recovery using essentially acoustic tomography that we have produced and then also the idea of a new geothermal energy scheme.

The next pictures are the ones that I referred to, and that is an idea that we are developing to use free electron laser photolithography for computer chip manufacture. Again, this is based on an SDI development at Los Alamos where we have developed the art of free electron lasers to the point where we can reach extremely short wavelengths. The key to the whole area of photolithography to be able to put a lot of information on a semiconductor chip depends on the wavelength of the light. With the free-electron laser, we think we can get down to very short wavelengths.

If you look at the one particular graph that is titled Sub-tenth Micron Features, we think we can get down to sub-tenth micron features on a semiconductor chip. This particular graph shows how today we use mercury lamps and are able to get maybe a million bits per chip. Today Sematech is developing deep ultraviolet lasers, as is Japan, where you might be able to get into the tens of millions. Tomorrow, IBM and others are developing X-ray synchrotron lithography where you might be able to get up into the hundreds of millions.

We think with free-electron lasers you should be able to get into the thousands of megabits, a gigabit, or the same integration density that you currently have on a Cray computer. That is not going to be easy. We are working with IBM, with Texas Instruments and also with Intel to see whether we can merge the capabilities of our laser scientists with the semiconductor capabilities in industry.

The next example is associated with our work in health care and on AIDS. We have worked in health effects essentially since our beginning because our interest was on the effects of ionizing radiation on humankind. Since that time, as was already brought out earlier this morning, we have gone off in many other directions to use the special capabilities at the lab, such as enormous computational computer capabilities where we have the world's largest scientific computational horsepower anywhere at Los Alamos, as well as laser base diagnostics and so forth.

The idea shown on this particular viewgraph that I call real-time laser diagnostics for future applications in medicine is to try to get at the issue of health care costs by doing real-time diagnosis in patients using lasers. Essentially anywhere that you can get a needle, an endoscope or any sort of a catheter, you would be able to introduce laser light and do real-time diagnostics.

The examples that I show here are essentially what we call a smart endoscope, or to do medication monitoring in real time or blood component analysis in real time. Again, these are all opened up by the enormous investments in laser technology at laboratories such as the three that are represented here.

Let me go on and make just a few final comments. I will not go through the rest of the examples in drugs or terrorism or in education except to say that they are contained in my full-length statement. I just hope that I have given in these few minutes some glimpse of the new directions to things that we are doing and that we are capable of doing and that we do bridge this gap between the basic research orientation of universities and the manufacturing application focus of industry.

There are many factors that contribute to our success over the years. Some of them have been discussed earlier this morning. There are two that I want to single out. One is that we have had a focus on science, and there, the importance of basic research cannot be overstated. So, for instance, to have this laboratory discretion on research and development is absolutely crucial, and I thank this Committee for helping to set the record straight in the Senate after the action that was taken in the House.

The second important thing is just the nature and the funding of the nuclear weapons RD&T program. It has demanded a broad technology base. We are vertically integrated. We have that application focus, and we have a can-do attitude. These have allowed us to continue to attract the best people. Also, the government has invested its resources in our facilities, so that has allowed us to shine.

Let me just conclude with a remark to reiterate the comments that Senator McClure made so well just a few minutes ago, the importance of the nuclear weapons program to the world today.

First of all, we at Los Alamos are extremely proud that we have helped to preserve peace through the work we have done in nuclear weapons technology and in maintaining the deterrent. We have helped to buy time for the democracies of the world to flourish.

The job ahead of us now, I believe, is to help to build a lasting peace. As long as nuclear weapons are going to be around in the hands of the super powers and in the hands of many other developing nations, we must have a nuclear competence that is second to none. That nuclear competence means the ability to understand, design, manufacture, safeguard and retire those weapons from service. So that competence has evolved very carefully at these three laboratories represented here.

I look forward to the challenge because our job, indeed, has not been diminished, but certainly our priorities in what we do have been changed.

Let me stop at this point. Thank you for your attention.
[The prepared statement of Dr. Hecker follows:]

Science Making a Difference in the 21st Century

Statement by

Siegfried S. Hecker
Director of the
Los Alamos National Laboratory

Before the

U.S. Senate Commitee on
Energy and National Resources
Subcommittee on Energy Research
and Development

Dirksen Senate Office Building
Washington, DC

July 25, 1990

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Los Alamos: Science Making a Difference for the 21st Century

A Statement by Siegfried S. Hecker
Director, Los Alamos National Laboratory
before the
U.S. Senate Committee on Energy and Natural Resources
Subcommittee on Energy Research and Development

July 25, 1990

EXECUTIVE SUMMARY

One of my predecessors at Los Alamos, Dr. Norris Bradbury, observed "we don't build nuclear weapons to destroy people--we build them to buy time for the political leaders of the world to resolve their differences in other ways." Now, decades later, the remarkable events of 1989 have begun to resolve those differences. We at Los Alamos helped to buy that time by providing the nuclear weapons technology to ensure a viable deterrent and by avoiding being surprised technologically by our adversaries. But the public is asking for a peace dividend. Is Los Alamos' job finished? The same question was asked after the war. The answer then was no! And history has vindicated that response. I believe the answer is still no! The federal government has the responsibility to deliver a lasting peace as the first and foremost peace dividend. Yet, our role will change to reflect the new world order and the new challenges that are on the horizon.

The following concentrates on how the superb technical expertise and facilities at Los Alamos are and will be used to address the pressing national problems both for today and for the coming century, while maintaining the vigilance in defense that provides the nation with protection from the unexpected. Several examples of scientific work at Los Alamos are presented within a framework of problems of public concern.

Problems like:

- *environmental degradation* where clever new ideas like a field portable midget mass spectrometer will dramatically reduce the cost and time of characterizing environmental remediation sites; and where important new research idea promises to reduce the storage problem of defense nuclear waste from tens of thousands of years to several hundred by transmuting it with an accelerator.

- *energy* where Los Alamos initiated two cost-shared collaborative field tests before the first anniversary of our pilot program in reservoir imaging--tests that will enable recovery of millions of barrels of bypassed oil--and where our accomplishments in hot dry rock geothermal and fusion energy programs are laying the basis for essentially inexhaustible and environmentally benign energy sources for the future.

- *economic competitiveness* where Los Alamos is developing strategic partnerships with U.S. industry to bring the results of science into the marketplace in a more timely and cost-effective manner; and where work spun-off from our strategic defense laser efforts could be the key to U.S. chip producers recapturing the world market.

- *health care* where Los Alamos' studies on AIDS have shed new light on that deadly virus spread; where our human genome work could someday help prevent many human diseases; and where we are trailblazing in applying lasers to medical applications that include real-time patient diagnosis with the potential of significantly reducing health care costs.

- *drugs and terrorism* where Los Alamos computer models will aid in the nation's war on drugs by following the money trail; where our advanced instrumentation techniques will permit the sensitive detection of explosives to reduce the terrorist threat to our airlines; and where a new method of fingerprint detection will increase the ability of our law enforcement officials to catch and convict criminals.

- *education* where Los Alamos programs are involving students and teachers in the excitement of science through environmental monitoring and research.

What allows us to make significant contributions in these areas are the people, the facilities, and the can-do attitude developed as part of our defense mission. We know how to conduct large, complex technology projects where science makes a difference. We have developed an environment that encourages individual creativity, but also allows us to assemble teams of scientists and engineers to solve complex problems.

The importance of our statutory defense mission must be reiterated. We still live in a world with tens of thousands of nuclear weapons. As long as these exist in the hands of superpowers or developing (and often unstable) nations, the United States must retain the nuclear competence to understand, design, manufacture, safeguard, and retire the weapons from service. That technical competence has evolved carefully over almost half a century at the three DOE nuclear weapons laboratories: Los Alamos, Lawrence Livermore and Sandia. It exists nowhere else.

But recent world changes have altered our priorities to where we must now, first and foremost, help the nation build down its nuclear arsenal while preserving national security and global stability. We must enhance the inherent safety features in nuclear warheads and improve their security, survivability, command and control, and mitigate environmental impacts of their manufacture and retirement. Remaining at the forefront of science and technology to avoid being surprised by potential adversaries will become even more important as the arsenals become smaller. Our priorities will change, but the enormous burden and responsibilities we carry to preserve the nation's nuclear competence have not diminished.

INTRODUCTION

Technology is the engine that drives our economy, improves the quality of life and environment, and will continue to maintain our national security. The rate of technological progress and the intensity of international competition continue to accelerate. The United States must manage its technological resources wisely to turn its substantial technological abilities into a competitive edge.

The principal resources are universities, industry, and government and nonprofit laboratories. U.S. universities, of course, are the success story of the past 50 years. They remain the envy of the world. The technological capabilities of U.S. industry remain formidable and hold the key to future competitiveness, even though much has been written about the decline of U.S. industrial technological competitiveness. Today, I would like to address the role that the Department of Energy (DOE) laboratories, specifically the Los Alamos National Laboratory, can play in the U.S. technological resurgence and in solving the problems facing the nation.

How the DOE Laboratories Can Help

The DOE laboratories represent a significant technological resource for solving large, complex technical problems important to the nation. They bridge the gap between the basic research orientation of universities and the application/manufacturing focus of industry.

These laboratories are government-owned, contractor-operated (GOCO) institutions motivated by public service. They concentrate on R&D that is high risk (but offering high potential payoff) and long term, where continuity of effort is essential. They tackle problems that benefit the general public as opposed to private individuals or specific companies. Pioneered during the Manhattan Project, these Laboratories can be more aggresively utilized in new government - private sector partnerships that many policymakers and scholars call for today.

The broad science and technology base at the DOE laboratories has provided a flexibility to address technological problems as they emerge on the national scene. Historically, these were associated primarily with atomic energy, either for defense or commercial power. In the 1970s the missions of the laboratories were significantly expanded to deal with the energy crisis, as the Atomic Energy Commission evolved into the Department of Energy. In the 1980s, Congress and the Executive Branch began emphasizing the notion of technology transfer; that is, expediting the application of federally funded research at the laboratories into the private sector. The National Competitiveness Technology Transfer Act of 1989 added technology transfer to the mission of the DOE laboratories.

As we begin the decade of the 1990s, we are confronted with a radically changed geopolitical climate. U.S. resolve to remain strong and defend the ideals of democracy contributed to the internal collapse of communism. Almost five decades of deterrence bought us time to allow for democracies to flourish.

So today defense is not in the public spotlight. That is the way it should be. However, that change does not relieve the federal government of its first and foremost responsibility, to provide for the common defense of its people. As we remain strong in defense, we are now confronted with other concerns as we approach the next millenium. At the forefront is our concern for planet Earth and its environment. Additionally, we struggle to stay competitive in a world that has become essentially one marketplace. Many of the major concerns we face today as a society have a strong technological component—that is technology can help to solve the problem. Using the technological edge and working smarter is the American way.

How can the DOE laboratories help in solving the important problems facing the nation? To answer this question, let me cite a number of issues that are high on the list of public concerns and then demonstrate what the laboratories can do to help solve these problems.

My list is compiled from a number of public surveys and an assessment of those concerns that have significant technical components to their solutions. I will discuss the following:

1. Environmental Degradation
2. Energy
3. Economic Competitiveness
4. Health Care/AIDS
5. Drugs and Terrorism
6. Education
7. National Security/Defense

My examples will be drawn from our experience and our ideas at Los Alamos. Clearly, the story will be even more convincing for the entire DOE laboratory system.

Los Alamos: Putting Science to Work for the Nation

The Los Alamos National Laboratory was established to solve the most important problem of the day—build the first atomic bomb to end World War II. The federal government with the help of the University of California, the contractor, brought together some of the best minds in the world to do what many thought was an impossible job.

The heritage of our laboratory stems from those beginnings. We solve large, complex technological problems for the nation, demonstrating that science makes a difference. Over the years, we and our sister laboratories at Livermore and Sandia have developed vertically integrated R&D institutions that have an applications focus and are steeped in fundamental science. By vertical integration I mean the "research-to-retirement" responsibility that the laboratories are assigned for nuclear warheads. We work with the production plants to ensure that designs can be manufactured and with the armed services to ensure that we understand how the weapon will be stored, handled, and used until the ultimate dismantling of it. We have a responsibility from beginning to end. The nuclear weapons program has provided challenge, flexibility, and a breadth of science and technology that has allowed us to contribute to many problems of national importance.

The overriding importance of the nuclear deterrence mission plus the DOE's success in carrying it out has encouraged the federal government over the years to invest resources in our institutions. Today, they provide almost unmatched scientific and technical capabilities.

The annual operating budget at Los Alamos is $950 million, supported by close to $100 million in construction and capital equipment funds. Currently 54 percent of the operating budget supports our broad nuclear weapons technology responsibilities; 22 percent conventional and strategic defenses; and 24 percent civilian R&D, predominantly energy research and technologies.

At Los Alamos we house the world's most powerful scientific computing facility with a computing power exceeding 65 of the original Cray 1 supercomputers. We develop and operate large lasers, accelerators, and neutron sources that push the state of the art. We have characterization facilities housing the latest spectrographs, microscopes, and other sophisticated diagnostics. We have materials synthesis and processing facilities difficult to match at another single institution.

Most importantly, we continue to attract an outstanding scientific, engineering, and technical support staff. Our 3150 scientists and engineers represent virtually all disciplines and span the spectrum from the most basic science to applied technology. They work in an environment that not only fosters individual creativity but also encourages teamwork. They can be rapidly assembled into teams that tackle the most challenging problems.

Today Los Alamos is a national resource helping to provide the scientific leadership for the challenges of the 1990s and the 21st century. Our purpose and guiding vision are to put science to work to make a positive difference in the world. Without weakening our commitment to our defense mission, we are turning some of our considerable world-class expertise and resources to bear upon the problems that are foremost in the American public's mind.

NATIONAL PROBLEMS

ENVIRONMENTAL DEGRADATION

Greatly increased environment awareness began with Rachel Carson's *Silent Spring* in the 1960s and was launched with "Earth Day" in April 1970. Around the world people became aware of their environment. Between 1970 and 1985, Congress enacted almost twenty pieces of legislation concerned with our environment, safety, and health. Most of these have been reauthorized in the past five years. In this period, we have become conscious of acid rain, ozone depletion, clean air, hazardous and toxic wastes, and more recently, global climate change. These "environmental consequences" are primarily results of energy use, lifestyle, and population growth. The challenge for us is to address these problems in ways that safeguard the environment for future generations without crippling the economy.

A landmark court decision in 1984 brought federal facilities under the federal laws and required the DOE to comply with all of the federal regulations. This decision has required the DOE to play "catch-up" in the environmental arena. To make major progress, environmental cleanup R&D is needed to develop a new approach to help DOE solve its problems better, more inexpensively, and more quickly. In addition to radioactive contamination and waste, the principal DOE concerns are associated with common industrial pollutants such as volatile organic compounds and their effect on ground water, surface soils, and air quality.

Also, many of the technologies, such as (1) our midget mass spectrometer, (2) supercritical water oxidation , and (3) accelerator-driven transmutation of radioactive wastes, developed for environmental control and for cleaning up the nuclear weapons complex, will also be valuable to other federal agencies and, in fact, a number of our research activities are being cosponsored by the Department of Defense (DoD). These techniques will also be valuable to U.S. industry, both to help it meet the stringent environmental mandates it faces and, by technology transfer, to give it a competitive advantage in the environmental cleanup markets worldwide. Many other countries, especially those in Eastern Europe and the developing world, badly need inexpensive and effective means to address their environmental problems.

Los Alamos has been investigating many new technologies to address problems associated with waste characterization and cleanup, environmental control technologies, global change, ozone depletion, and clean air. Some have near-term solutions; others will take longer.

Specific examples include (1) development of a midget mass spectrometer for *in situ* organic analysis, (2) development of an integrated three-dimensional underground imaging system, and (3) application of supercritical fluid approaches to treat contaminated water.

Midget Mass Spectrometer

In order to characterize a suspected waste site, we need to determine the exact types of potential contaminants, their precise location, and the amounts in which they might exist. Current procedures require an extensive number of samples (soil, water, and sometimes air), careful quality control of these samples in their removal to a certified laboratory, and subsequent comprehensive analysis. Collecting and analyzing a typical sample costs about $5,000 and requires five to six weeks. If one is willing to pay more for the analysis, the time can be reduced to three to four weeks. For some DOE facilities, characterization costs may well exceed $1 billion. Obviously, any new technology that can reduce costs even by a small fraction will have a big payoff. A constraint on moving new characterization and cleanup technologies into the field is that before they can be placed into actual use, extensive demonstration field operations with approval of the Environmental Protection Agency (EPA) are required.

Los Alamos has been developing a technology that could potentially reduce total (and not just organic) sampling costs by as much as 20 to 30 percent and reduce sampling times for volatile organic compounds from several weeks to 20 minutes. This transportable field instrument, called the midget mass spectrometer, is a gas chromatograph, ion-trap spectrometer for the *in situ* characterization of volatile organic contaminants at waste sites. This instrument is being developed to identify site boundaries, characterize chemical contaminants, and monitor and document the progress of site restoration. Use of the transportable midget mass spectrometer should lead to a reduction of health risks and cost and should improve remediation schedules.

The midget mass spectrometer is based on a modular design and can be readily modified in the field for air, water, or soil sampling. Volatile organic compounds are separated by heating before their introduction to the ion trap for mass spectral analysis. A microprocessor provides control. The spectrometer is fast, and analyses can be accomplished in an automated 20-minute procedure in the field. The spectrometer is very sensitive with detection limits better than those required by current EPA regulation. The detection limit for trichloroethylene in water, for example, is in the low part-per-trillion range. The spectrometer will analyze 60 EPA-specified organic compounds, which makes it unique for field-transportable spectrometers. The instrument has already been used under field conditions for soil analysis at a chemical waste site. We are planning a field demonstration targeted towards obtaining EPA certification this fall. We are working closely with one U.S. company to build the prototype instrument. We are pursuing collaborations with other companies.

The midget mass spectrometer is not the total solution for site characterization. It will not analyze inorganic compounds, heavy metals, and radionuclides. Field analysis of these elements will require new technologies. In addition, approximately one-half the cost for a sample is associated with paperwork, tracing, and quality control. Obviously, technology can play a role in reducing these costs.

Supercritical Water Oxidation

A wide spectrum of hazardous wastes can be destroyed by oxidation in supercritical water. In this process, water above its critical point is used as a carrier fluid for selected wastes and oxidant. Waste destruction takes place completely and rapidly at relatively low temperatures with full control of all effluents. Supercritical water

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THE FIELD TRANSPORTABLE MIDGET MASS SPECTROMETER PROVIDES HIGHLY SENSITIVE ANALYSIS AT 30% LOWER COST

- Automated operation, technician operated
- Analyzes for 60 EPA regulated volatile organic compounds
- 20 minutes per sample in the field
- Sensitivity 10 to 1000 times greater than required

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oxidation appears to have several advantages: (1) reactions can proceed rapidly to completion in a single stage, (2) all effluents can be fully controlled, (3) few or no oxides of nitrogen are formed because of the low temperature, (4) a system can be physically small for a given capacity, (5) the technology lends itself to remote or automatic control, and (6) it appears to be applicable to many wastes. It can be scaled from use in small laboratories to very large installations for decontamination of aquifers. Los Alamos is evaluating and developing this technology for application to a wide variety of DOE and DoD wastes.

We have shown that the chemical mechanisms in the supercritical water regime are related to those in ordinary gas-phase oxidation, which provides a basis for scaling the process using information currently available in the literature. Essentially complete destruction of selected wastes, including the organic components surrogates of high-level mixed wastes and actual propellants, has been demonstrated. An integrated project with Hanford, Rocky Flats, Savannah River, Sandia, and industry to apply the technology to waste management problems within the DOE complex is being established to help clean up the complex. This technology will be evaluated, for example, for treatment of the complex concentrate wastes at Hanford before vitrification or grouting. We recently held a workshop with industry--both potential users and suppliers--and are coordinating efforts closely with several companies.

A key application in which this technology could make a difference is cleanup of contaminated water with low concentrations of hazardous chemicals, for example, ground water, process waste water, or lagoons. On-site cleanup of soils is another application to be examined. This application may have advantages over incineration for a wide range of hazardous wastes because it does not produce nitrogen oxides at the low operating temperatures and it provides full control of all effluents. It seems to be particularly suited for destroying dilute concentrations of toxic organic chemicals in water.

Global Change

Properly safeguarding our environment for future generations without crippling our economy and standard of living will be one of the greatest challenges we face for the remainder of this century and the next. The potential impact of man-made contributions to global climate change and the environment are enormously complex, both technologically and sociologically.

Laboratories such as Los Alamos possess the fundamental skills and broad multidisciplinary capabilities to help sort out the complicated factors that influence acid rain, smog, ozone depletion, and the greenhouse effect.

Los Alamos possesses four major capabilities that will enable it to make large contributions to solutions of these global problems:

- An ongoing program to simulate global climate over several years on supercomputers with computations of weather that are compared with global data sets.
- A multifaceted capability for remote sensing of atmospheric motions and constituents from the ground, stratosphere, and space.
- A massive capability to solve very complex problems using the most advanced supercomputers, the numerical methods necessary for the simulations, and the computer graphics equipment to display the results.
- A history of conducting large, multidisciplinary research development programs, which includes collaborations with industry and universities.

Three examples serve to illustrate recent accomplishments in global change:

1. Los Alamos is introducing a sophisticated cloud model into a three-dimensional global climate code that accurately simulates global heat transport and precipitation (a problem common to global climate codes in general). This work is being done in collaboration with the University of California's Scripps Institute of Oceanography.

2. Los Alamos is developing a mobile LIDAR (light detector and ranging) unit to study water vapor content and motions near the Earth's surface, including evapo-transporation from trees and plants. Results can vastly improve models and data used in computer codes.

3. In support of the DOE's Computer Hardware, Advanced Mathematics, and Model Physics initiative to increase the speed of global climate codes by a factor of 10,000, Los Alamos is currently implementing large ocean and atmospheric codes on one of its 65,000-processor, massively parallel Thinking Machines' CM-2 supercomputers. This work is being done in collaboration with Thinking Machines, Inc.

Plans for the future include:

- Development of a coupled ocean/atmosphere advanced climate model that will take advantage of advances in supercomputing architecture and developments in numerical methods for massively parallel computing. These efforts will make use of the Los Alamos component of the Science and Technology Center for Advanced Computing funded by the National Science Foundation.

- Development of methods for efficiently collecting, analyzing, and assimilating huge amounts of remotely sensed climate data and integrating it interactively with large computer simulations of climate.

Accelerator-Driven Transmutation of Radioactive Wastes

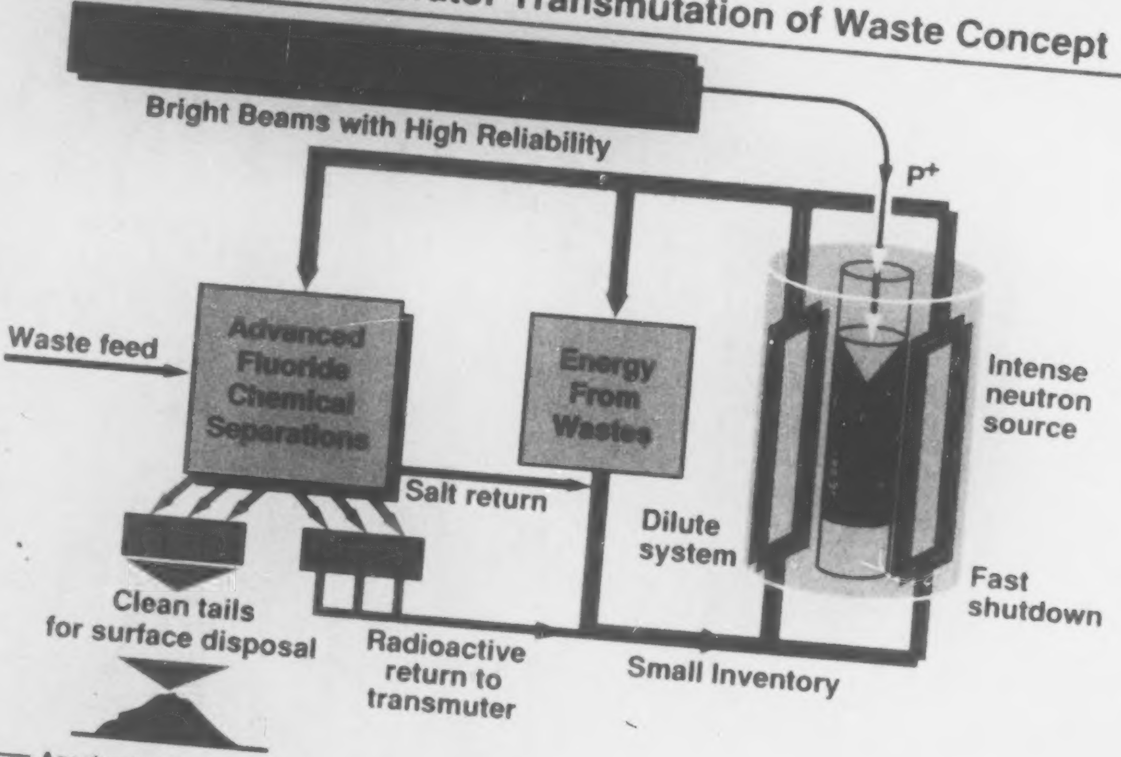
We propose research on a dramatically new, innovative, and potentially high payoff approach to solving problems associated with defense nuclear waste management and disposal. Our approach is built around transmutation of long-lived nuclear wastes to short-lived or stable isotopes using an intense accelerator-driven spallation neutron source. While transmutation concepts applied to nuclear wastes have been studied for many years, we believe that two exciting discoveries recently made at Los Alamos open significant new parameter regimes for the development of safe and effective transmutation concepts.

Present nuclear waste strategies, centered around geologic repository storage, require geologic stability and separation of wastes from human contact for tens to hundreds of thousands of years. While we believe currently planned sites would safely contain wastes over such time scales, public acceptance has been difficult to achieve. Transmutation offers the potential for transforming the time scales associated with nuclear wastes from tens of thousands to hundreds of years. Geologic or managed storage would still be needed, but for only one to several centuries. We believe this dramatic reduction in time scales would help meet major public concerns surrounding nuclear waste disposal.

As previously mentioned, two important discoveries have generated significant technical excitement concerning a dramatic new approach to accelerator-based transmutation of long-lived nuclear wastes. Recent high-energy, high-current accelerator development under way at Los Alamos permits design of high-intensity spallation sources of low-energy (thermal) neutrons. Fluxes in these designs are so high (about 100 times greater than standard reactor designs) that two significant advances are possible. First, higher actinides (such as neptunium-237) can be converted rapidly using low-energy neutrons. This process can occur only in a high-flux environment where compound nuclei that are produced are fissioned rapidly. Low-energy neutrons also permit rapid conversion of long-lived fission products such as technetium-99. High neutron fluxes also allow a new, very dilute operating regime that permits high transmutation rates using very low inventories of fissile materials. Our system achieves yearly amounts of transmuted material that are similar to those from reactor or conventional accelerator-based concepts. However, our approach requires 100-200 times less resident actinide materials than conventional designs.

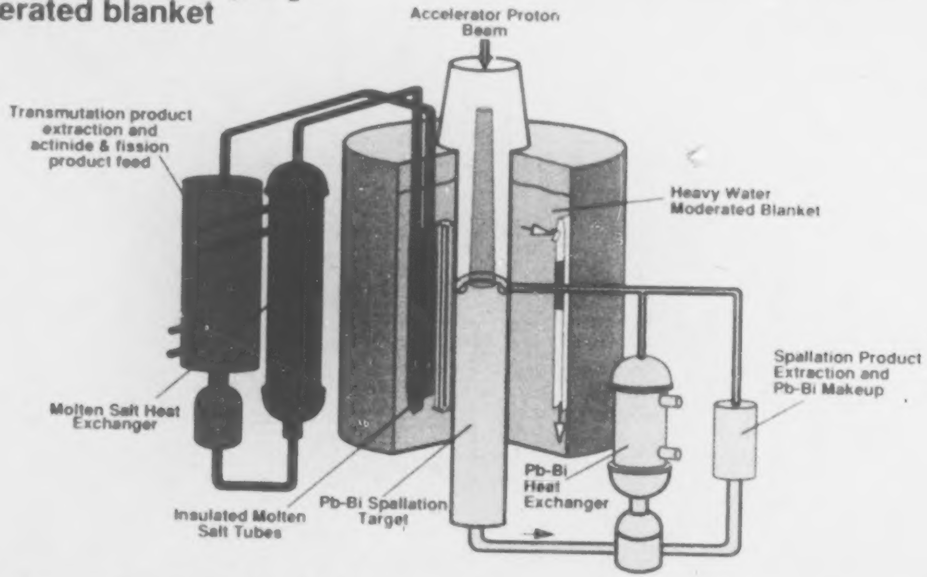
Our research strategy centers around developing new Los Alamos technology advances for eventual application to transmutation of long-lived nuclear wastes that exist at facilities such as Hanford, Savannah River, and Idaho Falls. These wastes result mainly from processing associated with nuclear weapons materials and naval reactor fuel production. They exist in separated (chemically partitioned) forms, ideal for their introduction into a transmutation system. Eliminating these wastes represent an area of pressing need associated with DOE's cleanup of the production complex. We believe that

Los Alamos Accelerator Transmutation of Waste Concept


Bright Beams with High Reliability
p^+
Waste feed
Advanced Fluoride Chemical Separations
Energy From Wastes
Salt return
Intense neutron source
Dilute system
Fast shutdown
Clean tails for surface disposal
Radioactive return to transmuter
Small Inventory

Accelerator Transmutation of Waste Design

- Accelerator driven
- Lead-bismuth spallation neutron production
- Low fissile inventory, D_2O moderated blanket
- Flowing molten salt waste carrier
- Continuous processing
- Optional power production


Accelerator Proton Beam
Transmutation product extraction and actinide & fission product feed
Heavy Water Moderated Blanket
Molten Salt Heat Exchanger
Spallation Product Extraction and Pb-Bi Makeup
Pb-Bi Heat Exchanger
Insulated Molten Salt Tubes
Pb-Bi Spallation Target

investigation and development of a transmutation strategy would help demonstrate the DOE's commitment to finding the best possible solutions to management and disposal of nuclear wastes.

Using thermal neutrons, a transmutation system can possibly be developed that can efficiently handle defense wastes. Under this transmutation strategy, the residual radiotoxicity of the waste can be reduced to a level no greater than the natural radiotoxicity of the uranium that was consumed in producing the waste. Without transmutation, hundreds of thousands of years would be required for the radioactive materials to naturally decay to these levels.

A companion feature of the high transmutation rate, low inventory system is a continuous, on-line chemical process capable of very high decontamination factors. The system uses a molten fluoride salt matrix to move the transmutables quickly through the target volume into a purifier that separates the decontaminated product materials for safe disposal. The system uses recent developments in fluorine chemistry, along with the proven separation performance from ion exchange and distillation processes, to assure high quality decontamination of the final product. This type of process also minimizes any collateral waste from the chemical processes necessary to transmutation.

With a successful research and development program, we estimate that by the year 2005 the first such system could be in place at one of the DOE sites having large inventories of high-level and transuranic wastes -- Hanford, Savannah River, or Idaho. To accomplish this requires a series of development and demonstration steps culminating in a prototype system operating in 1998. Such a prototype would consist of a full-energy, lower-current accelerator that would demonstrate operating conditions associated with the full-current facility. Before construction of the prototype, several R&D activities would be initiated in parallel.

Our assessment of needed technologies and expected near-term development leads to our estimate that a production facility could possibly be completed by the end of the projected 15-year period. Although we are confident of the fundamental principles of our new concept, we recognize that the technology associated with all subsystem areas - accelerator, target, chemistry processing, materials - will be challenging and difficult. Furthermore, such a system would not be inexpensive; a full production facility would likely cost several billion dollars. However, demonstration of successful defense-waste transmutation system would resolve a major DOE problem.

ENERGY

The energy crisis of the 1970s made the nation aware of our dependence on imported oil and led to the concept of energy security. In the 1980s, the public perception was that the energy crisis had diminished to no more than just a continuing problem. However, even though energy has dropped out of the public's eye, the energy crisis has become more of an energy "ulcer" as our trade deficit hemorrhages to pay for ever and ever more imported oil, thus reducing energy and economic security. Furthermore, as previously mentioned, the global environmental issues of acid rain, ozone depletion, clean air, and global change are directly related to energy use. Recent legislation in global change and clean air will have major economic and supply implications for the energy industry, as well as the public.

Transportation accounts for a major portion of oil consumption in the U.S., and emissions associated with transportation are major contributors to pollution. Transportation gridlock/skylock increases fuel use and emissions. Yet we still have no proven new technology alternative to the internal combustion engine. Although this causes concern, it provides opportunity as well. New environmental control technologies related to energy, and new environmentally acceptable energy technologies can provide export opportunities to U.S. industry, enhancing our competitiveness. New, fuel-efficient and environmentally sound transportation technologies can do the same. Thus, we see that the issues associated with energy, environmental, and economic security are closely intertwined, and all are part of our national security.

Los Alamos has engaged in energy research and development as an element of its mission since the early 1950s. With the advent of the energy crisis in the 1970s, the scope of our energy research, as with all of the DOE national laboratories, was accelerated and enhanced. Although the fraction of energy research and development within the Laboratory's portfolio has decreased in the 1980s, it remains critically important to our nation's security. As we look to the future, we see many potential contributions that we can make to the nation's energy, environmental, and economic security. I will cover three examples that illustrate near-term, mid-term, and long-term energy contributions.

Improved Oil Recovery: A Near-Term Example Where Technology Can Make a Difference

After a long period of stability, domestic oil production has begun to decline and oil imports, which now provide half of our needs, are increasing. Oil wells in the United States are being abandoned at an alarming rate, and even the most optimistic forecasts project increasing dependence on imports from the Middle East. However, known reservoirs in the United States contain twice as much oil as we have produced in our history and, over the years, the United States has produced more oil than any other nation. Of the massive 340-billion-barrel resource remaining within the borders of the United States, estimates are that an additional 76 billion barrels could be made economically recoverable with technologies that could be developed within the next decade. Seventy-six billion barrels is roughly one-half of all the oil that has been produced in United States history.

We are assessing the possibilities for technological improvements and we are increasingly encouraged by our analysis and our interactions with the industry. These interactions led to the creation of the Oil Recovery Technology Partnership, which the DOE established in the Fall of 1988. The Partnership allies the Department of Energy, Los Alamos and Sandia National Laboratories, and the petroleum industry. The national laboratories play a dual role in this Partnership: one role is that of technology supplier to industry, and the other role is that of "honest broker" in collaborations among normally competing companies.

In the first role, our commitment to the Partnership is to quickly modify and transfer technologies developed for defense or energy programs to the petroleum industry. The Partnership is organized to place industry in the driver's seat at three different levels: policy, technology, and project. At the policy level, the Partnership Steering Committee insures that Partnership projects are addressing the highest-priority needs of the petroleum industry and that the projects represent a well-balanced technical approach. At the technology level, an Industry Review Panel reviews the projects. Then, at the project level, each project is structured as a collaboration between one of the Laboratories and one or more companies.

Twelve major oil companies, eight independents, and eight service companies formally participate in the Oil Recovery Technology Partnership on either the steering committee, the technical review panel, or the crosswell seismic forum.

The first Los Alamos field test under Partnership auspices was conducted last summer in collaboration with Murphy Operating Corporation, a New Mexico independent producer. The field test featured a technique called microseismic fracture mapping and was conducted to determine whether this technique had sufficient sensitivity to map fractures in an operating oil field. Conducted in the Chaveroo field, in the Permian Basin stretching from Southeastern New Mexico into West Texas, the test confirmed our original hypothesis, showing sharp increases in seismic activity correlating with production operations. Conductive fractures located near injection wells can channel away water used to flood the field, leaving large portions of the reservoir unswept. Microseismic fracture mapping can enable oil producers to understand the fracture geometry in their fields and alter the flooding strategy. If our preliminary results are confirmed, 8 to 10 million more barrels of oil could be recovered from the Chaveroo field alone through more effective waterflooding. An important feature of this test-one that was made possible by the structure of the Oil Recovery Technology Partnership-was that we were in the field with Murphy Operating Corporation just five months after we first made contact. This field test cast Los Alamos in the role of technology provider to a small independent producer.

Our second field test cast the Laboratory in a dual role as both technology provider and as "honest broker," bringing together a collaborative effort involving Texaco U.S.A., Chevron Oil Field Research Company, Amoco, Exxon, and Stanford University under the leadership of Los Alamos. The field tests were conducted in Texaco wells in California's McKittrick field, using crosswell seismic imaging technology that is analogous to the medical "CAT scans," but on a scale appropriate to an oil reservoir. Texaco donated five wells to the project, deferring production for two months and risking losing a well to the test of a new technology. The test was highly successful. A "CAT scan" image of a fault showed a bypassed accumulation of heavy crude oil. *Advanced Technology Week*

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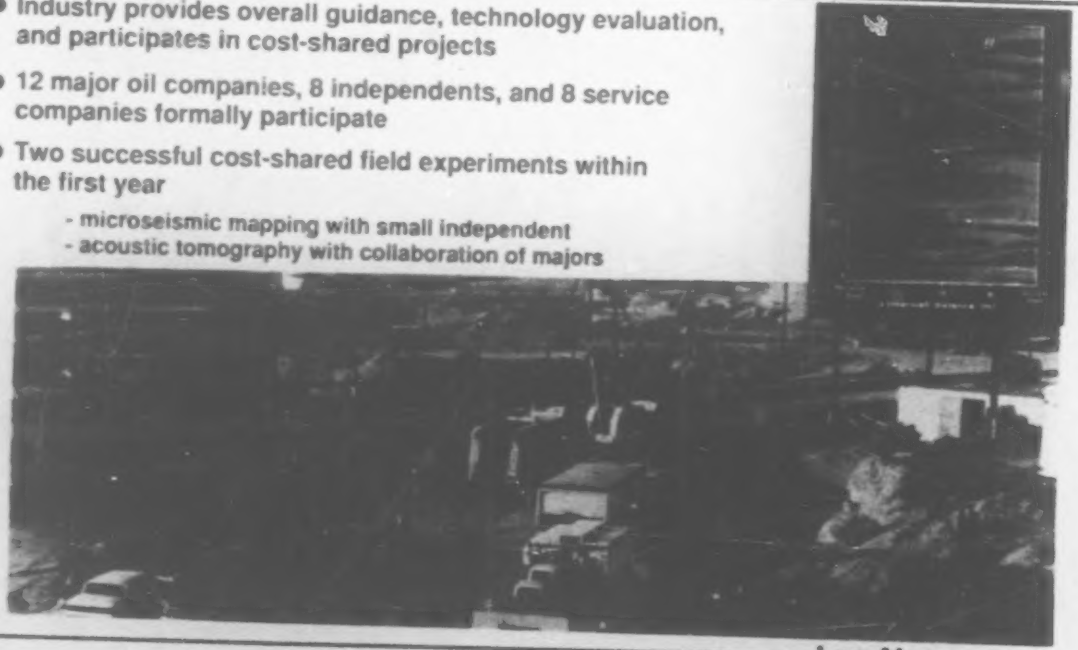
The Oil Recovery Technology Partnership allies the Department of Energy, Los Alamos and Sandia National Laboratories and the United States petroleum industry

- Industry provides overall guidance, technology evaluation, and participates in cost-shared projects
- 12 major oil companies, 8 independents, and 8 service companies formally participate
- Two successful cost-shared field experiments within the first year
    - microseismic mapping with small independent
    - acoustic tomography with collaboration of majors



Los Alamos

reported in the April 16, 1990 issue that Texaco plans to perforate a well to test the apparently bypassed pool, which is a prime target for recovery.

Both of these field experiments were initiated before the first anniversary of the Oil Recovery Technology Partnership. This demonstrates that, in the proper situation and with the right technology, the federal government, along with the national laboratories, can rapidly make major impacts.

Geothermal Energy: Extracting the Energy from Hot Dry Rock within the Earth

The Hot Dry Rock (HDR) geothermal energy technology is an environmentally benign renewable energy source that can contribute to the nation's balanced and diversified energy mix. The Department of Energy sponsors the HDR Program, and Los Alamos has primary responsibility for the program. HDR geothermal reservoirs differ profoundly from conventional geothermal reservoirs. The latter, usually referred to as hydrothermal reservoirs, are rarely found and are only in few geologically favored regions in the Western United States. In contrast, HDR energy reservoirs are man-made, and thus any convenient source of hot, solid rock can serve as the host reservoir. Hot rock can be found at fairly shallow depths throughout the U.S. An evaluation of the potentially useful heat in HDR at accessible depths beneath the United States indicates that its energy content is several thousand times the total energy used in this nation in one year. HDR potential exists in the Northeast, Mid-Atlantic, Western, as well as the Mid-Western regions of the United States. The potential worldwide is also enormous.

The HDR method for recovering heat from the earth's crust is to drill two wells and connect them through a series of cracks or fractures produced by pressurizing one of the wells. Water pumped down one well is heated as it circulates through the fractures and returns to the surface through the other well. Heat exchangers extract the useful heat, and the water recirculates and recovers more heat. The removed heat can be used directly or converted to electricity. Because this is a closed-circulation loop, with minor releases to the biosphere, the system is environmentally benign.

Several years ago Los Alamos completed the world's first hot dry rock system at Fenton Hill in the mountains of Northern New Mexico. The year-long operation brought hot water to the surface at a temperature of about 140°C (280°F). Los Alamos has since undertaken development of a larger, deeper, and hotter system. For the past few years, Los Alamos has been readying the wells and site for an extended flow test, a major milestone of the program. Beginning next year, we plan to operate this system for one to two years in order to determine reservoir lifetime and total heat extraction rate and to continue environmental surveillance. This will provide the necessary information for U.S. industry to make informed investment decisions about the technology.

Industrial participation has always been an integral part of the hot dry rock heat mining program. The HDR facilities have been constructed by private industrial organizations with experience in petroleum and conventional geothermal drilling and completion. Los Alamos has developed specialized tools and equipment jointly with industry. Industry participation in the operation of the Fenton Hill system during extended flow testing is anticipated. The technology provides a unique opportunity to revitalize the oil and gas drilling and service industries. Because of its potential as an economically competitive and environmentally acceptable worldwide resource and it is typically small unit size (e.g. 50MWe), HDR could provide export opportunities to U.S. industry for developing countries.

Fusion: Inexhaustible Fuel for the Future

Since the 1950s, Los Alamos has engaged in research on controlled fusion energy, the process that powers the sun and other stars. Fusion offers an attractive energy option, with essentially inexhaustible fuel and desirable safety and environmental features. In fact, fusion may ultimately be the most desirable, central-station power source.

Fusion has long been recognized as a major energy candidate for the future, and its role is being re-examined in the context of a national energy strategy. The pace of progress in the development of fusion has not always met expectations. Early optimism in the 1950s was replaced in the early 1960s by doubts that net energy could ever be achieved. However, major advances since that time reaffirm the potential of fusion as an energy source. Technical readiness for taking major new steps in the program must be evaluated. Thus, a review is being carried out by the Fusion Policy Advisory Committee (FPAC) at the request of Secretary James D. Watkins.

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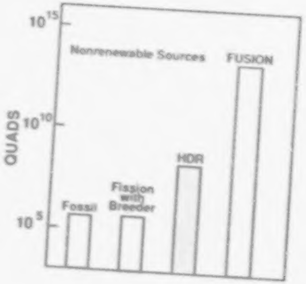
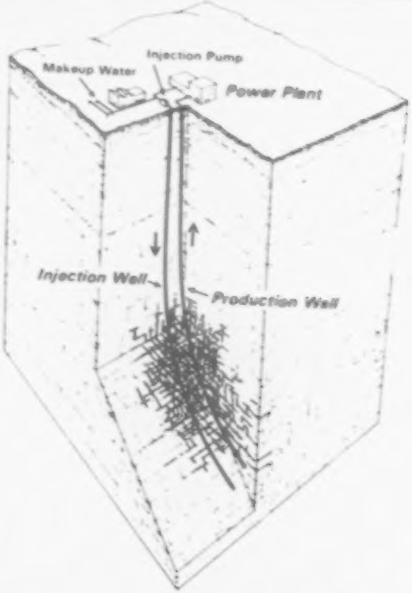
HOT DRY ROCK GEOTHERMAL ENERGY PROVIDES AN ENVIRONMENTALLY ACCEPTABLE RENEWABLE ENERGY OPTION

- Enormous resource base, encompassing much of the United States
- Potentially cost competitive with coal
- Potential to revitalize domestic oil and gas drilling/services industry
- Export opportunities exploiting worldwide resources




Makeup Water
Injection Pump
Power Plant
Injection Well
Production Well

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The FPAC is examining the two major approaches to fusion: magnetic confinement and inertial confinement. Some of the leaders of the Magnetic Fusion Energy program submitted a plan to FPAC last March that recommends a well-defined strategy to demonstrate early in the 21st century that fusion is a practical, safe, reliable, and environmentally attractive energy source. We support that plan, which culminates in a fusion power demonstration facility in the United States that would produce net electric power and provide a basis for fusion commercialization. The FPAC has been developing similar plans that would incorporate the inertial confinement approach into the overall strategy.

The fusion program is characterized by challenging science and technology. For the fusion process to proceed at useful rates, the fusion fuel must be heated to about 100 million degrees. At these temperatures, electrons are stripped from atoms, and the resulting gas of free electrons and atomic nuclei is called a plasma. In the sun and other stars, gravity confines the hot plasma and sustains the fusion process.

The hot plasma can be controlled in the laboratory by using magnetic fields, and several promising magnetic field configurations have been developed. The study of several configurations facilitates the understanding of plasma behavior and improves the prediction of performance in more advanced fusion devices in the future. Substantial progress has led to improved plasma control and confinement with favorable projections for developing reactors that can produce electrical power at acceptable cost.

Another method of achieving fusion consists of heating small dense pellets of fuel very quickly by intense laser or particle beam drivers before the inertia of the fuel allows the pellet to fly apart. This inertial confinement approach was also marked by overly optimistic predictions in the early 1970s, but recent advances in both the pellet (target) physics and technical advances in drivers indicate that it has potential as an approach for fusion power.

The role of Los Alamos in the Magnetic Fusion Energy program is to contribute to the goal of demonstrating magnetic fusion as a practical energy source. The main focus is on magnetic configurations such as the reversed field pinch, that might lead to significantly smaller and simpler fusion systems than those based on the present mainline tokamak configuration. The tokamak has been very successful in demonstrating progress in achieving fusion parameters near ignition, and it is the only configuration that could be used in the near future to demonstrate high fusion-power gain. However, improvements are needed to achieve a commercially attractive power source. Scientific advances in understanding the reversed-field pinch configuration enhance its potential of leading to a fusion system that requires less complex technologies for both the magnets and the plasma heating systems. The resulting reduced size and complexity would enhance commercial attractiveness. We have been remarkably successful with reversed-field pinch experiments in our ZT-40 device, and we are currently constructing a larger, next-generation experiment called the ZTH, to be completed in 1993. ZTH is the first experiment in the CPRF (Confinement Physics Research Facility), which is also under construction at Los Alamos. Together they are about 70 percent complete, and they will provide a flexible experimental resource for fusion research far into the future.

In the inertial confinement program, Los Alamos is developing the krypton fluoride (KrF) laser as a potential driver for an inertial fusion energy system. Advantageous properties of the KrF laser include efficient energy coupling to the gas lasing medium that would allow the rapid firing needed for power production applications and strong coupling to the target. The Aurora facility at Los Alamos is the largest KrF system in the world. It has achieved power densities of over 100 TW/cm^2 and now operates in a regime useful for target experiments. Over the next three to four years, Aurora will be used to evaluate KrF for fusion driver applications.

We are also developing technology that is essential for both magnetic and inertial fusion. We are using the Tritium Systems Test Assembly (TSTA), a unique world resource for tritium technology, to demonstrate the fuel cycle for fusion power systems, to develop and evaluate advanced safety systems for personnel and environmental protection, to develop and test components, and to demonstrate the long-term, routine safe handling of tritium for large-scale fusion reactor systems.

The contributions of Los Alamos in developing the reversed-field pinch, KrF lasers, and tritium technologies are important in achieving a practical and attractive fusion power source before the middle of the next century.

ECONOMIC COMPETITIVENESS

The post-World War II leadership of the United States in the research, development, manufacture, and marketing of advanced technology is quickly being eroded by other nations. Our ability to continue pushing the leading edge of science and technology is being jeopardized by this lost ground. Technological leadership is essential if the United States is to retain a viable industrial economy, be competitive in the world marketplace, and be capable technically and financially of providing for energy independence, ecological security, and national security.

Future advances in science and technology in areas such as supercomputing, biomedical technologies, and energy technologies are expected to enable solutions to profound global and societal problems such as global climate change, AIDS, and oil dependency. The United States must expand its capabilities in these high-leverage strategic technology areas in order to enable the timely and cost-effective design and development of new composite materials; electronic components; advanced commercial and military air- and spacecraft; advanced energy systems; computer systems capable of speech recognition and language understanding; and other advanced technology items upon which our national welfare will depend. In particular, because the technological competition in these advanced technologies is so acute, the United States government should encourage R&D in technologies that hold out the possibility of leapfrogging one or more generations of technology, thereby permitting a competitive advantage that few other nations can match. An example of leapfrog technology being developed today at Los Alamos involves the use of laser technology spun off from our Strategic Defence Initiative work. This revolutionary concept is described later in this testimony.

Competitor nations have a national understanding of the technological and economic implications of the future and have focused coherent rational efforts to achieve dominance in a multitude of high-technology areas of particularly high leverage. For example, over the past fifteen years the Japanese Ministry of International Trade and Industry (MITI) has provided critical planning, support, and guidance for a number of national-level government-industry cooperative ventures aimed at gaining technological leadership. Such undertakings include highly successful R&D projects in Very Large Scale

Integration (VLSI), advanced telecommunications, second-generation optoelectronic integrated circuits, and superconductivity. The Japanese themselves indirectly acknowledge the worth of this government-industry collaborative approach as they show no signs of changing direction. Indeed, in a recent report the Japanese Government announced that it is developing plans for a concerted effort to dominate the field of massively parallel processing -- seen by many experts as the key to future supercomputing, an area in which the United States today enjoys leadership.

For their part, European industries with significant government support and subsidy have launched massive transnational efforts to gain technological dominance in the areas of High-Definition Television (HDTV), advanced communications, and industrial technologies. This transnational strategy that promotes government-industry cooperation has worked remarkably well for the European Community in the manufacture of commercial aircraft and represents the determination of the British, French, and German governments to break into the commercial-aircraft industry traditionally dominated by U.S. firms. In a little less than a decade, Airbus has become a serious global competitor. In 1986, its new orders exceeded those of the giant U.S. firm McDonnell Douglas, and in 1987 it accounted for 23 percent of all new orders worldwide.

As a result of such close government-industry interaction and cooperation, the Japanese and Western Europeans are gaining leadership positions in such key technological areas as semiconductors, advanced materials, supercomputers, and superconductivity. In particular, the Japanese have excelled in quickly and economically translating U.S. research results into commercial applications - a capability that results in significant measure from Japanese corporate collaboration with government early in the technology development cycle.

An increasing number of respected experts have begun to argue that a purely macroeconomic approach to America's competitiveness problems is insufficient. Without disputing the importance of the macroeconomic environment, proponents of these views, of which I am one, believe that the competitive challenge from abroad is such that macroeconomic change and fine-tuning will not by themselves change our long term competitiveness. The role of technology, manufacturing productivity, and generally events inside and among individual factories, laboratories, and universities represent the ground truth of the national economy.

Recognizing such realities, Los Alamos has helped develop a new model in government-industry collaboration that allows the government to more effectively leverage its research investment and U.S. industry to engage in the sort of high-risk, high-potential payoff research that it is otherwise increasingly abandoning today. This approach is exemplified in our Superconductivity Pilot Center described below. As will also be seen, we have proposed that the same approach be extended to high-performance computing to help maintain U.S. preeminence in that vitally important technology.

XUV-FEL Photolithography

The United States no longer leads the world market in microelectronics, a technology it invented. Since 1974, the U. S. market share in dynamic random access memory chips has fallen from 100 percent to less than 20 percent; its market share for semiconductor manufacturing equipment has fallen from nearly 100 percent to 20-40 percent, depending on the equipment type, and its share in semiconductor electronics is declining. These trends pose a serious threat to a strategic U. S. technology and industry.

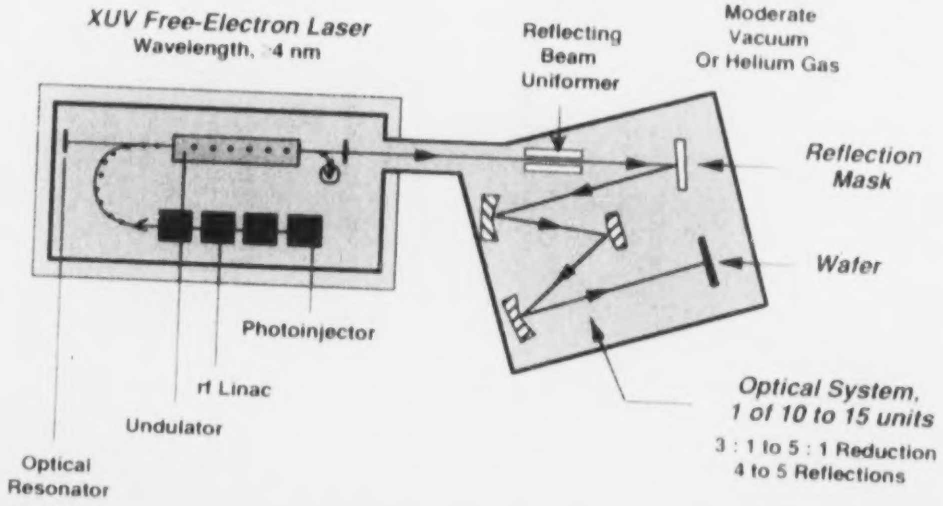
The threat is pervasive, and its nature lies in the control and access to electronics. In the defense sector, many essential items of defense electronics contain a substantial number of microelectronics devices that are manufactured offshore. Our fastest and most powerful computers contain Japanese memory chips. In the private sector, electronic industries provide about 10 percent of all manufacturing jobs, and most make extensive use of microelectronics. To remain competitive, electronic industries must have timely access to new technologies and be able to integrate them into producible, marketable products. The declining U. S. market share has eroded our production capacity.

The United States has responded assertively to this threat by developing lithography tools that produce much greater numbers of semiconductor devices on a chip and thus enable the creation of higher-performance chips. Key to the U. S. approach is the use of very short wavelength light to create accompanying small feature size. Sematech is pursuing the use of a tool based on ultraviolet light lasers; IBM is developing synchrotron x-ray light sources; others are developing approaches based on the production of x-rays from laser-produced plasmas. All of these tools seek to produce feature sizes of about 0.25 microns and would be used for chips that would be introduced into the market by about the middle of this decade. Yet, the likelihood that these necessary efforts will result in a significant recovery in market share is low: Japan is pursuing the same approaches, they are investing far more resources in their development efforts, and they will compete intensively. Furthermore, these lithography tools have limitations that may prevent their use for chips after about 2000 AD when feature sizes much less than 0.2 microns will be required. There is no cohesive U. S. program aimed at producing these very small feature sizes.

One approach to recovery lies in developing a lithography tool that gives U. S. industry a strong and enduring competitive advantage in the post-2000 AD market. Such a tool can be achieved by using a free-electron laser (FEL) that produces extreme ultraviolet (XUV) light at a wavelength of 4-10 nanometers and a projection optical system that utilizes mirrors rather than lenses. We believe that such a system can produce feature sizes of less than 0.1 microns (perhaps as low as 0.05 microns), about 3 to 5 times less than the value intended for the near-term competition described above. The leapfrog strategy for this approach is straightforward: 1) rapidly develop the XUV-FEL tool in parallel with the important and necessary near-term efforts; 2) conduct the development precompetitively in collaboration with academia and industry; 3) complete an industry prototype lithography tool by the mid-1990s that is capable of 0.15-micron feature size; 4) introduce these products in about 2000 AD when the market requires them; and 5) continue the timely development of the lithography tool to produce feature sizes down to about 0.05 microns, which should assure strong U. S. presence in the market for a decade.

The free-electron laser in the XUV-FEL projection lithography concept consists of a high-performance electron beam accelerator, bending magnets, an undulator that converts the electron beam energy to light, and special mirrors that enhance the energy conversion and direct the light to the projection system. The FEL can produce about 100 watts of ultraviolet light at a single wavelength, in contrast to plasma and synchrotron light sources that produce light at much lower power. The soundness of the FEL approach is

Los Alamos Approach to 0.1-μm Resolution Lithography Will Use an XUV Free-Electron Laser, A Reflecting Mask and Projection System, and Surface-Imaging Resists


XUV Free-Electron Laser
Wavelength, ~4 nm
Reflecting Beam Uniformer
Moderate Vacuum Or Helium Gas
Reflection Mask
Wafer
Photoinjector
rf Linac
Undulator
Optical Resonator
Optical System, 1 of 10 to 15 units
3 : 1 to 5 : 1 Reduction
4 to 5 Reflections

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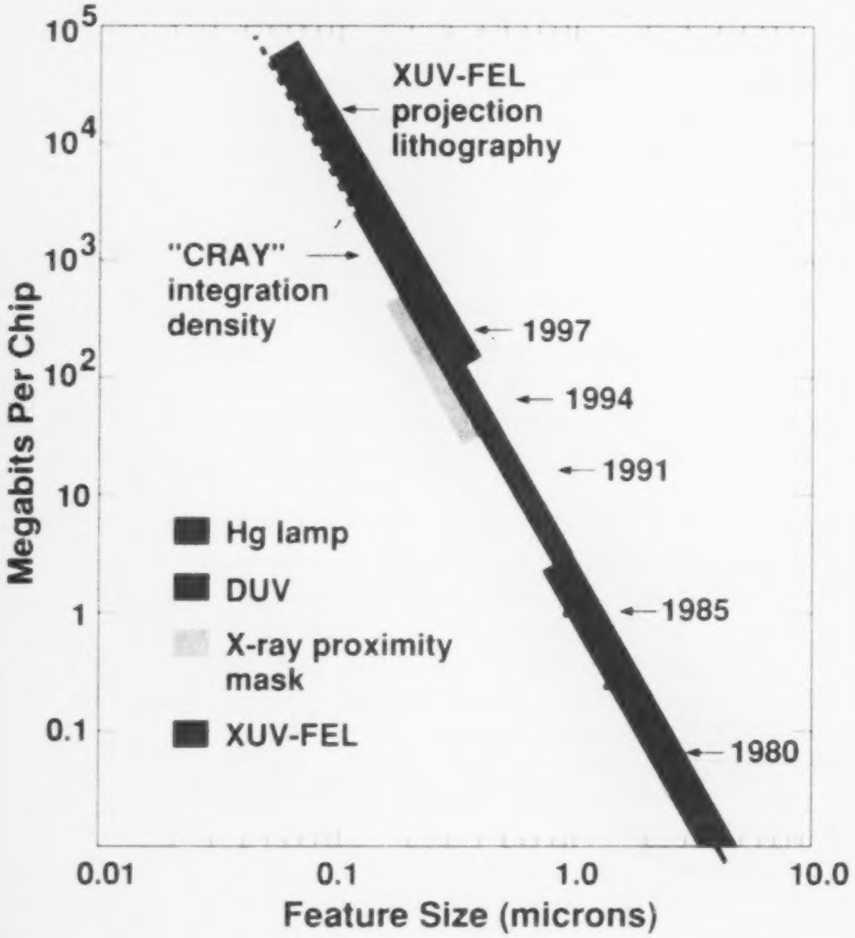
Sub-Tenth Micron Features Will Enable Ultimate Large-Scale Integration



Los Alamos

based on the several-hundred-million-dollar investment by the Strategic Defense Initiative Organization in FEL technology for ballistic missile defense and has resulted in the high level of experimental and theoretical sophistication that enables the application of FEL technology to this dual use. Because of this investment, the United States leads the world in this technology.

Light from the XUV-FEL is sent to a reflecting mask and from there to a multimirror optical system that produces an image of the mask detail on a wafer. Reflecting optics are required because no satisfactory transmitting materials in these wavelength and power regimes. The multimirror imaging device must produce a distortion-free image of about one square inch on the wafer. This approach has several advantageous features: the size of the mask may be ten times larger than the image on the chip, thus facilitating the fabrication and repair of the mask; and the high power of the XUV-FEL permits the simultaneous use of 10-15 wafer steppers and a very short exposure time (thus enhancing factory processing).

The ability to develop sub-tenth-micron features in the XUV-FEL approach will enable extremely high large-scale integration. The domain of the XUV-FEL is below about 0.2-micron feature size. At its entry level, chip integration densities of about 1 billion devices per chip are conceptually possible; this is about the same number of semiconductor devices in a Cray Y-MP computer. Even higher integration densities enabled by the XUV-FEL lithography approach may permit revolutionary advances in high-performance computing (e. g., global weather prediction) and in the massive information processing required by global surveillance of the earth's environment and treaty verification.

Industries such as Texas Instruments, IBM, and Intel have expressed interest in the XUV-FEL concept, and we are discussing potential collaboration. Semiconductor Research Corporation has also expressed strong interest at seeing a comprehensive evaluation of the concept. Interest and collaboration from the private sector will be crucial before we can proceed. Because of its traditional interest in lasers and optics, the DOE has also indicated an interest in supporting this effort. We have also held preliminary discussions with the Defense Advanced Projects Research Agency.

In summary, the application of a technology developed for strategic defense permits the creation of an enduring competitive advantage for a strategic U. S. technology and fuels the progress of an industry whose products are inextricably woven into our defense and civilian economies.

The DOE Superconductivity Pilot Center Experiment

In October 1988, DOE launched an important experiment in strategic alliances by announcing the establishment of Superconductivity Pilot Centers at Argonne, Los Alamos, and Oak Ridge national laboratories. This experiment is designed to test the ability of the national laboratories to work effectively with U.S. industry on strategic technologies, to contribute significantly to industry's introduction of commercial products to the marketplace, and, thus, to assist in enhancing the competitive position of the United States in worldwide technological markets.

The principal functions of the Los Alamos Superconductivity Pilot Center are (1) to seek out industrial partners, (2) to interact with them in all phases of the innovation and development cycle for high-temperature superconductivity devices and applications, and (3) to facilitate industrial innovation and commercialization by focusing exploratory R&D on the enabling technologies that are critical to early commercial application of ceramic superconductors.

Our Pilot Center has made substantial progress in its first year and a half. We have twelve R&D agreements currently in place with companies ranging from small start-ups to some of the largest U.S.-based organizations. The total value of these agreements exceeds $13 million over three years. One of our major cooperative projects involves DuPont and Hewlett Packard and is directed toward the development of electronic components using high-temperature superconducting thin films. This effort has made significant progress and a passive, microwave prototype device will be completed this summer and will be considered for commercialization by our industrial partners. Other new agreements are being explored with industrial partners.

Los Alamos has a strong technical program in high-temperature superconductivity with substantial results and advances reported in a number of areas including the theoretical understanding of the phenomenon of high-temperature superconductivity itself; materials synthesis, production, and processing, especially thin films and wires/tapes; fabrication of prototype devices for commercial and defense applications; and development of diagnostic instrumentation. Using these technical strengths, the Pilot Center acts as a magnet to draw together government and industry scientists and engineers with faculty and students from U.S. universities, thereby helping to create a stronger future talent base for superconductivity applications.

FY 1991 funding in the President's Budget is $5 million for each of the centers. The pilot center concept is being recognized as an effective model for National Laboratory/U.S. industry partnerships to develop strategic technologies that are important to the economic competitiveness and military security of the nation.

High-Performance Computing

High-performance computing is the heart of our technological engine. Virtually everything depends on it today, from addressing the complex problem of global climate change to getting airplane tickets. A 1985 White House Science Council report stated: "....the bottom line is that any country that seeks to control its future must effectively exploit high performance computing...."

However, for several years there has been growing concern that our nation is losing its leadership in computing. We have lost the lead in computer chip manufacturing, and not only are other nations beginning to produce very impressive supercomputers, the industrial base in other nations (in particular, Japan) is beginning to apply supercomputing to its needs more extensively than is being done in the United States.

Supercomputing originated with the "Los Alamos Problem"--as mathematically predicting the performance of the first atomic bomb was called during the Manhattan Project. The first attempts at supercomputing were made by organized teams of operators with arrays of mechanical desk-top calculators. In 1945, Los Alamos researchers running their problem were the first users of the University of Pennsylvania ENIAC, the world's first large-scale electronic computer.

Shortly thereafter, Los Alamos implemented the John von Neumann "stored program" architecture into its own MANIAC computer, with which it ran the first large-scale hydrodynamic calculations for the thermonuclear bomb. We worked closely with IBM and received its first supercomputer, model 701, in 1953 and continued that relationship for over a decade. We developed a long-standing working relationship with Seymour Cray in the mid-sixties and in time had four of Control Data's first supercomputers. When Cray went on his own, we received the first Cray 1 in 1976 with no operating system and no software. The close collaboration between Cray, the entrepreneurial supplier, and Los Alamos, the sophisticated and demanding user, was key to the success of Cray computers.

Los Alamos continues to play a lead role in high-performance computing today. We are a sophisticated, pace-setting user. We continue to work cooperatively with vendors (Cray Research, Cray Computers, IBM, DEC, Thinking Machines Corporation, etc.). And we have developed and licensed software and hardware crucial to future supercomputing environments. We are also working as a member of an NSF Science and Technology Center on the next step to higher performance, massively parallel processing with machines with architectures like the Thinking Machines Corporation CM-2.

To protect the U.S. lead against formidable Japanese competition will require a joint government/industry investment strategy that nurtures the type of cooperative laboratory/industry ventures that I have just described.

Such ventures should exploit current trends in high-performance computing which include (1) new computer hardware architectures such as massively-parallel computers, (2) real-time visualization to allow a user to watch and interact with a calculation as it develops, (3) powerful scientific workstations to place immense computing power and flexibility literally on the desktop of a user, (4) high-speed networking to facilitate the use of a scientific workstation with a central supercomputer and to allow sharing of distributed computing hardware and data bases over long geographical distances, and (5) new computer software and algorithms that take advantage of new computer architectures and distributed computing.

Los Alamos has turned much of its attention and collaborations in these directions. The high-performance computing environment we are developing consists of powerful workstations at an individual's workplace connected to high-speed and functionally transparent networks that connect to supercomputers. Hence, the task is one of integrating three different functionalities--workstations, networks, and supercomputers--into a seamless, distributed environment.

Last March in a hearing before this Subcommittee on S.1976 (the DOE High-Performance Computing Act of 1990), I proposed the creation of a few (3-5) Collaborative R&D Centers (CRDCs) to help implement a laboratory/industry venture. A CRDC would be led by one organization that has a strong history in computing (such as Los Alamos does in collaborating with industry, effectively using computing, and being driven itself by demanding applications) but would be composed of several other organizations including other federal labs, the academic community, computing technology developers, and industrial users (or would-be users) of advanced computing tools.

The primary goals of the CRDCs would be to

- collaborate with computing vendors to keep the United States at the leading edge and
- impart knowledge and facilitate effective application of computing tools by U.S. business and industry.

Other aspects of a CRDC would include providing opportunities and challenges for graduate students, developing related enabling technologies such as FEL lithography and superconducting electronics, and creating a general user program to make computing more available and more useful to greater segments of the population.

Like the highly successful DOE Superconductivity Pilot Centers established at Los Alamos, Oak Ridge, and Argonne National Laboratories in 1988, the CRDCs should be collaborative centers in three senses of the word: (1) they should work with universities to incorporate the latest ideas into high-performance computing; (2) they should work with industry to set common goals and objectives; and (3) they should be jointly sponsored by the government and private industry. The DOE and its laboratories can and should play a leading role in helping this nation strengthen its lead in high-performance computing and in applying the technology to problems of importance to U.S. industry.

Computer Applications Software

There are many examples of how high power computing capability can favorably impact economic competitiveness. Computer simulation of combustion phenomena has recently been developed to help improve efficiency and reduce emissions. Los Alamos has been a leader in the field of computer modeling of combustion and in developing advanced multidimensional, multiphase, reactive flow computer programs for the analysis of practical combustion systems.

Analyzing such systems typically involves solving coupled partial differential equations for fluid flow with multiple species transport, heat transfer, turbulence, and chemical reactions. Often the fuel for combustion is introduced by means of a liquid spray, and solution of the fluid equations must be coupled to solution of equations for the spray dynamics.

KIVA-II is the most recent in a series of computer programs that has been developed at Los Alamos for such analyses. The primary applications are the simulation of in-cylinder dynamics of internal combustion engines. However, because the equations and solution procedures are very general, the code has broad applicability to steady and unsteady combustion systems involving both low- and high-speed flows. The wide acceptance and usage of KIVA-II by the combustion design community indicates the utility of this analysis approach in helping to design cleaner, more efficient combustion systems.

KIVA-II is currently being used to predict many trends in automotive engine performance and to gain physical insight into in-cylinder flow fields. Every major automotive manufacturer has a copy of KIVA-II, and the code is being used for engine design by General Motors. In addition to internal combustion applications, KIVA-II is being used to simulate flows in stationary spray and coal slurry combustors, mixing and combustion in supersonic streams for application to the National Aerospace Plane (NASP) project, combustion instabilities in jet and rocket engines, and hydrogen/air combustion for reactor safety applications. A national KIVA users group has been formed to encourage use of KIVA-II, to encourage communication between users, and to identify important issues for code development.

KIVA-II is being developed further to improve its accuracy and extend its applicability. Our present understanding of turbulent transport and its interaction with chemistry and multiphase flows limits the accuracy of current combustion models and poses the greatest challenge for future analyses. More geometric flexibility will also be desirable for future applications. Although much research and development remains, it is important to realize that we are fast approaching a time when computer simulations will be a routine stage in the design of practical combustion systems.

In another example of computing applications software, we return to the Manhattan Project and the advent of digital computers. Since these early days, the nuclear weapons laboratories have been world leaders in computing how subatomic particles interact with matter. The Monte Carlo method, a mathematical method used to simulate the flow of radiation, was invented at Los Alamos. The principal Los Alamos Monte Carlo computer code, MCNP, can simulate a wide variety of complex probabilistic (random) natural phenomena. MCNP is now the international standard radiation transport computer code in many areas of great value to American competitiveness. It is used by the oil industry to model oil-well logging tools; it is used by hospitals and medical research centers to model strategies for cancer therapy; and it is used by the nuclear criticality safety community to ensure safety in nuclear design. It is also used in the areas of space exploration, aerospace, defense, nuclear reactors, fusion energy, and nondestructive assay. Around 50 organizations per year request copies of MCNP. Today, about 50 large industrial companies, 25 major universities, and 25 of the larger federal laboratories use MCNP regularly.

HEALTH CARE/AIDS

Along with defense, health and human welfare are primary responsibilities of the federal government. And, indeed, the United States spends more on basic research in the life sciences than in any other field. The payoffs have been dramatic. The federal investment in molecular biology has revolutionized the field of medicine. Hardly a day goes by without another exciting announcement of the wonders of modern medicine. And yet, we have just begun to scratch the surface of potential benefits to humankind.

One troubling element has been the skyrocketing cost of health care. Sophistication in medical treatments has resulted in improved quality and duration of life, but at a concomitant increase in cost. Today we spend over $500 billion (or more than 11 percent of our gross national product) on health care. That amounts to approximately $2000 for every woman, man, and child, a twelve-fold increase in 25 years.

Struggling to contain costs, companies are hiking employee premiums and hiring "health management" consultants to second-guess doctors. Nearly 37 million Americans in the work force have no health insurance whatsoever. The AIDS epidemic has put an added burden on a strained system, adding as much as $6 billion in health costs by 1991. Modern medical technology clearly must be directed at the containment of health care costs as well as improving the quality of life.

Los Alamos can help. In fact, the DOE and its laboratories have a distinguished record of applying the science and technology base of defense and energy programs to biomedical research and technologies. Early medical interest stemmed from concern for the biological effects of ionizing radiation. Many of the techniques used in radioisotope medicine were developed by the DOE laboratories. They have continued to develop medical applications based on their strength in accelerators, lasers, computers, and multidisciplinary science.

I will discuss some of the accomplishments and novel ideas at Los Alamos in biological and biomedical research. We are poised to contribute to the delivery of health care as well as to reduce its cost.

Cancer Treatment with Linear Accelerators

All linear accelerators used in hospitals for radiation treatment of cancer are based on the Los Alamos design of a side-coupled linear accelerator (LINAC) cavity. The original work in 1965 applied to the design of the half-mile-long accelerator for the Los Alamos Meson Physics Facility (LAMPF), a facility that is still the mainstay of medium-energy physics research in this nation.

Varian Associates became aware of the Los Alamos technology, recognized its potential, and adapted it for medical use. Today, Varian is the leading producer of medical radiation accelerators in the world.

The Los Alamos accelerator design resulted in a compact, efficient unit for diagnosis and cancer therapy. It is suitable for installation in community hospitals as well as in large metropolitan hospitals. As of March 1990, approximately 2000 machines had been built for cancer treatment using the Los Alamos technology. Varian estimates that approximately 10 million people have been treated with the accelerators. About one-third of the patients have been cured, and most of the others have benefited from the treatment.

In addition to cancer treatment, the machines are in use worldwide for nondestructive testing and inspection of such devices as rocket motors, pressure valves, and airline jet engines. Varian sales to date of these accelerator-based diagnostic units amount to about a billion dollars, and the economic activity generated in the world is substantially greater. In comparison, the original construction cost of LAMPF was $56 million.

AIDS Model

The AIDS epidemic has very serious implications for this country and indeed the world. We must recognize and deal with not only the human tragedy but also the tremendous impact on the nation's health care delivery system. To effectively use information on AIDS transmission, susceptibility of individuals, and disease progression to predict the possible outcome of the epidemic requires that data obtained from population studies be clearly understood.

About five years ago, Los Alamos scientists set out to apply quantitative modeling techniques to the epidemiological data on the rates of HIV (human immunodeficiency virus) infection and the occurrence of AIDS. Because the time delay between HIV infection and symptomatic AIDS was unknown, as was the rate of infectivity (the number of contacts required to produce HIV infection), scientists felt that modeling what *was* known might shed light on the unknown.

The first apparent result from the models was that the growth of the number of symptomatic AIDS cases from mid-1982 was cubic in time rather than exponential, as one would expect if the number of infections grew proportionately to the number of cases. This finding means that the growth rate decreases with time. Although the growth *rates* are different in each population, the cubic dependence for cumulative cases also holds for subgroups by race, sex, and sexual preference.

To try to understand this pattern, our scientists developed a model of transmission based on risk behavior. This approach makes it possible to model the spread of the disease within and between groups with different risk behaviors. As a result, we can use the model to test different strategies to prevent the spread of the disease and make quantitative determinations as to their effectiveness.

Quite apart from the effectiveness or usefulness of the model per se, this work has spurred efforts to gather and make available valid data on the prevalence of HIV infection and AIDS. An Office of Science and Technology Policy workshop came out of these efforts, and the group is currently working with the State Department and the U.S. Agency for International Development to help model and understand the future course of the epidemic.

GenBank and National Research Resource for AIDS Sequences

In the late 1970s it became clear that nucleic acid sequencing would become a major tool in biological and biomedical research. Scientists realized that as the amount of information grew exponentially, computers must be used to store and analyze the data. Los Alamos scientists pioneered in the development of, and have become foremost practitioners in, the use of computational tools in research. As a result, Los Alamos is the site of two computational national resources.

The GenBank nucleic acid data base is a computer-based collection of all published DNA and RNA sequences and is the primary source of nucleic-acid sequence information for the scientific and medical communities. Nucleic acids contain the genetic information required by all living things, and the identity of the sequences is absolutely essential in determining how life processes function.

GenBank contains sequences of over 34 million nucleotide bases that are the building blocks of nucleic acids. The approximately 29,000 individual entries are drawn from published articles. Each sequence is accompanied by relevant biological information. The data base is made available to users, of which there are over 20,000 worldwide.

GenBank is a cooperative venture funded by the National Institutes of Health and cosponsored by the National Library of Medicine and the Department of Energy. Los Alamos constructs the data base and Intelligenetics distributes it. International collaborators with GenBank include the European Molecular Biology Laboratory and the DNA Database of Japan.

Building on the GenBank experience, the National Research Resource for AIDS Sequences was established at the Laboratory nearly three years ago. Sponsored by an interagency agreement between the National Institutes of Health and the Department of Energy, the Resource provides AIDS researchers with up-to-date information on viruses that mutate extraordinarily rapidly. Because of the rapid rate of change induced by mutation, the disease is very difficult to deal with in the clinic. The information supplied by the Resource will facilitate efforts in basic research on treatment and prevention.

The data base contains information derived from HIV and related retroviruses and has five components: nucleotide sequences, amino acid sequences, analysis packages, sequences related to the HIV, and data base communications. From just rudimentary HIV sequence information two years ago, sequence information for 48 different HIV and related sequences has been obtained and entered into the data base.

Medical Applications of Laser Technology

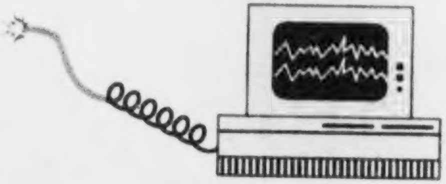
The use of lasers in medicine is growing rapidly and to such good effect that surgery in the year 2000 will be very different from and much less invasive than surgery today. Eye surgery including reshaping corneas to correct vision defects and laser angioplasty to clean out clogged corneal arteries are popular examples of current or impending laser procedures impacting the health of the nation.

As impressive as these new techniques are, they are just the bare beginnings of what is possible. In general, laser procedures reduce trauma (and thus reduce cost) and laser diagnostics work in real time in the body. These advantages offer considerable incentive to develop more laser applications in medicine, but the field presently suffers from a lack of underlying basic research. Most current applications have been developed from situation-specific research driven by focused commercial motives. Attaining the extraordinary promise of lasers in medicine will require long-term programs of basic research in laser effects. Such programs will entail unprecedented interdisciplinary communication and cooperation, combining high levels of laser, medical, and business expertise.

Over the past 15 years the DOE has spent over $500 million at Los Alamos to develop a broad base of expertise and physical capabilities in lasers and their applications. We are in an excellent position to help the medical community and the private sector with both basic research and specific applications.

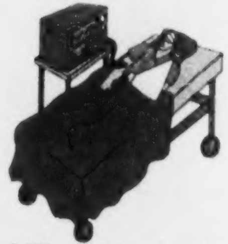
Although we desire to develop a major program, Los Alamos has already started a series of small programs in which we have demonstrated that we can work effectively with the medical community. We are, for example, a National Resource for Flow Cytometry, a laser-based technique for sorting out individual cells that has applications to the Human Genome Project. In another example, our laser scientists have established an effective network of interactions and proposed projects with a number of medical entities, prime among which are the Lovelace Clinic (Albuquerque) and the Medical School of the University of New Mexico. Finally, we have successfully completed several ophthalmological projects for private industry and are currently working on a commercially funded investigation of laser effects in urology. One interesting aspect of the latter program is that lithotripsy, or the shattering of urological stones with laser-generated shock waves, can be computer-modeled by an adaptation of a large Los Alamos computer code developed for modeling laser fusion.

Smart Endoscope



Computer Controlled Endoscope for Real-Time Detection of Cancer

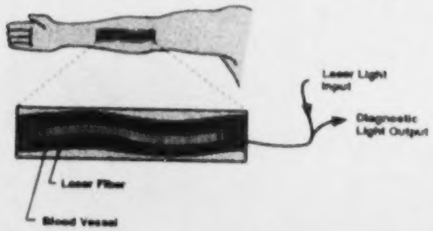
Medication Monitoring



Real-Time Monitoring of Medication Levels

Real-Time Laser Diagnostics for Future Applications in Medicine

Blood Component Analysis


Laser Light Input
Diagnostic Light Output
Laser Fiber
Blood Vessel

Continuous Real-time Analysis of Critical Blood Components

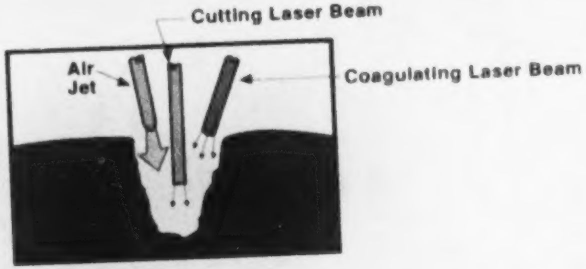
Los Alamos

[illegible]

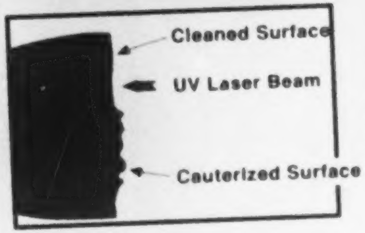
Liver Transection

- Because of the extreme perfusion of blood in the liver it now takes 6-8 hours to make one transection.
- If this time could be reduced, the regeneration of the liver could be exploited --- one donor liver could be implanted in three recipients.

Cutting Approach:


Cutting Laser Beam
Air Jet
Coagulating Laser Beam

Followed by Debridement:


Cleaned Surface
UV Laser Beam
Cauterized Surface

The cleaned surface will regenerate more effectively than a cauterized and charred surface.

Los Alamos

For the near term, let me cite a few examples to illustrate the extraordinary promise of lasers in medicine:

1. Real-time monitoring of medication levels in trauma situations using laser-interrogated, implanted optical fibers.
2. In a similar fashion, longer-term monitoring of blood components (for instance, detection of enzymes that indicate the return of liver function after a liver transplant).
3. Real-time detection of cancer by laser-induced fluorescence of the tissue as viewed through an endoscope, thereby avoiding the trauma and delay of biopsy analysis.
4. A combined laser and detector apparatus with a parallel-running computer program to create reliable laser-welded unions in blood vessels and tissue.
5. The development of effective and rapid laser techniques for dividing the liver. (The control of bleeding by surgical techniques is such a major problem that one transection takes 6-8 hours.)
6. The ability to kill isolated tumors (such as those in liver cancer) by laser heating (hyperthermia). Because the laser energy is deliverable by an optical fiber inserted through a needle, such procedures are minimally traumatic.

In a longer time frame, the payoffs from continuing basic research can be expected to be nothing short of miraculous. With the caveat that these are very high-risk predictions, we can envision examples like the following:

1. Laser cutting and growth stimulation techniques that will, for the first time, allow repairs of injuries to the central nervous system and make it possible to transplant eyes.

2. The implementation of high-average-power free-electron laser systems for greatly improved and less traumatic treatments of serious burn cases using selective ablation for wound cleaning.

3. Combinations of laser procedures that would revolutionize battlefield trauma control through thermal nerve blocking anesthesia and rapid wound closure.

4. Investigations of the spectroscopy of blood that would result in the ability to selectively kill viruses; for example, in an external laser-irradiated blood flow cell.

To serve the national good, these programs must have as their steadfast goal the solving of real medical problems, as opposed to producing solutions for which problems must be found. We believe that Los Alamos National Laboratory has established a track record in the kind of cooperative projects required to make meaningful contributions to the art of medical practice and to carry out the transfer of technology to private industry.

Human Genome Project

This project is dedicated to the complete characterization of the human genome. It is a milestone endeavor to map each of the human chromosomes and ultimately decipher the genetic information that is the basis of all life.

The human genome is the complete set of instructions for the development and function of the human body, and these instructions have a profound impact on how well and how long each individual will live. The genome contains all the deoxyribonucleic acid (DNA) in a cell, and it is the DNA, the chemical bearer of genetic information, that is passed from parents to offspring by the chromosomes. The chromosomes contain approximately 100,000 genes, which are portions of the chromosome's DNA that control the production of specific products, each having a specific (and generally crucial) function.

The revolutionary understanding gained through this project will have profound effects on the quality of both medicine and our technological competitiveness, not in a century, but in our lifetime.

- Genes involved in more than 4000 genetic diseases can be found. Changes in a single gene can cause diseases that can be passed from parents to offspring, including cystic fibrosis, muscular dystrophy, hemophilia, sickle-cell anemia, and Huntington's disease. It cost about $150 million to isolate the gene for cystic fibrosis. At an estimated cost of $3 billion for the entire 15-year project, only $30,000 per gene would be spent. Not only is the Project the ONLY way to understand the genetic component of complex human disorders, it is undoubtedly the most cost effective as well.

- The most common illnesses of which virtually all of us will have first-hand experience are multigenic. They are the result of many genes and include cancer, heart disease, and mental disorders. While these diseases cannot be inherited, each has a very important genetic component.

- Disease diagnosis and treatment will become immeasurably more accurate and informative with the potential for individualized health care practice and preventive medicine.

- Technology acquisition and transfer will enhance economic competitiveness and assure continued leadership in biotechnology.

The DOE was the first to develop a program plan and fund individual initiatives within the Human Genome Project. The DOE recognized immediately that the Human Genome Project would require multidisciplinary skills in molecular biology, chemistry, engineering, physics, and computer science. Exploiting the traditional strength of the national laboratories in such efforts, the DOE designated Los Alamos and Lawrence Berkeley Laboratory as Centers for Human Genome Studies, and recently added the Lawrence Livermore National Laboratory.

The Centers were charged to develop programs in physical mapping, informatics, new technology development, and technology transfer. Los Alamos was given the additional charge of developing a pilot technology transfer effort that could serve as a model for other institutions serving the Project.

- Physical mapping. An immediate Project objective is construction of a physical map of each human chromosome. A physical map is an ordered array of DNA segments across a chromosome. This map will define the location of every DNA segment within the chromosome and will be used to pinpoint the location of genes and provide DNA for sequencing. Los Alamos has made remarkable progress in the development of techniques to rapidly produce physical maps and has assembled long contiguous regions representing 60 percent of human chromosome 16. Chromosome 16 contains a number of important genes, including one whose mutation is responsible for adult polycystic kidney disease (over 200,000 potential cases in the United States).

- Informatics. The Project will generate huge quantities of data. To gain a perspective of the data handling requirements, approximately one million pages of this size or a stack of pages 330 feet tall would be needed to simply print out the 3 billion bases composing the human genome; this printout would represent only a small fraction of the data that must be accumulated, stored, accessed, and analyzed. Los Alamos scientists pioneered the use of computational and computer science in biological and biomedical research and development, of which GenBank and the National Research Resource for AIDS Sequences are but two examples. Image analysis techniques recently developed and used at Los Alamos reduce the time and cost of data analysis for mapping by one to two orders of magnitude.

- New technology development. Before the promise of the Project can be realized, the effort required for sequencing bases must be reduced dramatically. Using advanced laser and computational techniques, Los Alamos scientists can now detect a single molecule. This achievement is equivalent to detecting a thimble full of molecules in an olympic-size swimming pool. This technology will be applied to rapid, inexpensive sequencing of large regions of human DNA and has the potential of increasing the rate of sequencing by three orders of magnitude.

- Technology transfer. Although the United States is the world leader in biotechnology, this leadership will not continue unchallenged. The Human Genome Project cannot succeed without developing new technologies, and these technologies must be quickly commercialized. I believe that we will meet the challenges. Indeed, recent successes at Los Alamos and elsewhere are only the early examples of what promises to be a flourishing enterprise.

A detailed understanding of the human genetic material is one of the most important scientific challenge facing mankind. Our nation has expended both human and financial resources to understand our universe and provide for our physical and economic security. It seems fitting that the skills and knowledge developed for those endeavors be applied to understanding ourselves as well.

DRUGS AND TERRORISM

Drugs and terrorism have become a dramatically increased threat to our society. United States citizens, at home or abroad, are too often the target of terrorist acts, and our borders are being bombarded by the illegal cargo of narcotics. With the proliferation of advanced weaponry, including antiaircraft missiles, short-range ballistic missiles, and chemical/biological agents, the equipment available to, and used by, terrorists has become more sophisticated. Their planning, operations, and targeting increasingly focus on the technological vulnerabilities of industrialized and industrializing societies. A 1987 Defense Science Board study indicated the number of active anti-American terrorists at close to 1000 with an aggregate budget of $200M. In 1987, there were 832 operations in 84 nations; 187 were state-sponsored. We are painfully familiar with the placement of explosive devices aboard aircraft.

Illegal narcotics threaten our social fabric and deplete our economic vitality. Drug sales in the U.S. are between $60-110B per year. This same amount of illegal cash is laundered through the bank system and much of it leaves the country. The size of this industry is comparable to the computing industry and two times larger than the pharmaceutical industry. Three-fourths of all robberies and half of all felony assaults committed by young people (statistically, the most crime-prone age group) now involve drug users. The single largest source of new HIV/AIDS virus infections and perhaps one-half of all AIDS deaths are drug-related. As many as 5 percent of U.S. babies are born each year to mothers who use drugs. Many of these infants suffer low birth weight, severe and often permanent mental and physical dysfunction or impairment, or signs of actual drug dependence. Many do not survive past infancy. The estimated burden to society in lost productivity and medical costs is conservatively $60B.

There do appear to be some distinct differences in the two "wars" being addressed. To counter terrorism, we will have to rely more on incisive intelligence and penetration of the terrorist organizations. The drug war will involve a much broader spectrum of attacks on the supply areas and processing sites, on the entire transportation and distribution system, and on the vigorous prosecution of the criminals through due civil process. Neither "war" can be won by technology and hardware alone. It is abundantly clear that there must be major demand-reduction efforts to "deter" the users of both drugs and terrorist tactics.

In many areas, the problems of countering terrorists and drug traffickers appear most similar at the R&D level, where detectors, trackers, "taggants," and physical surveillance devices can play a prominent role in apprehension and successful prosecution.

Some of the common needs for technology:

- Detect and identify suspect aircraft, vessels, and vehicles;
- Detect contraband in containers aboard ships, cars, or aircraft in ports of entry along borders or at sea, e.g., drugs, currency, explosives, and firearms.
- Detect smugglers and terrorists crossing borders, e.g., use available data bases through artificial intelligence and pattern recognition;
- Survey and track persons and objects; and
- Improve communications and intelligence, such as secure, miniaturized, worldwide and compatible voice/digital communications and expert systems to help quickly make sense out of the mountains of reports and sightings generated.

I will cite three examples today of Los Alamos technology that can make a difference in the fight against terrorism and narcotics.

Money Flow Model Project

International trade in illegal drugs is a multinational business. It affects banking, local economics, and many governments around the world. The amount of money involved in illegal drug trafficking is so great that U.S. Treasury Department officials have said that the illegal drug trade is "capable of destabilizing legitimate governments" and that the revenues from drug sales "could jeopardize the integrity of U.S. financial institutions."

The illegal drug industry in the United States may move almost as much money annually as OPEC or the U.S. computer manufacturing industry with profits perhaps as much as $150 billion a year. In comparison, the total revenues of the U.S. pharmaceutical research and manufacturing industries are approximately $43 billion a year (based on 1987 data). Cash from drug trafficking can provide funds for terrorists and governments to carry out political objectives such as destabilizing democracies, creating anarchy, or supporting revolutions.

It is estimated that about half of the illegal drug trade profits are invested in legitimate businesses in the United States - with the remainder invested abroad. On an average day, $160 - $400 million of illegal cash must be made to appear legal. Therefore, large volumes of cash are laundered daily by a wide range of commercial establishments, corporations, businesses, and banks. This cash trail offers a key to penetrating the illegal drug industry and interdicting the drug trade itself.

Many government agencies are involved in financial investigations and intelligence gathering on drug trafficking operations: Treasury, Customs, the Federal Bureau of Investigation, Department of Justice, the Internal Revenue Service, and others. To help these agencies target and locate illegal currency activities more quickly, Los Alamos National Laboratory is developing analytical tools that focus on domestic bulk-currency flows. Using banking data from various federal agencies and the Federal Reserve, intelligence information, and state-of-the-art statistical computer codes, we are developing a complex bulk cash flow model. This model will allow us to pinpoint regions and banks where unusually heavy and unexplained currency surpluses are occurring. This program makes use of the world class computational capability developed at Los Alamos over the years.

Our first task is to collect and organize data on currency shipments and deposits from the 12 Federal Reserve Districts on a bank-by-bank basis. Our world-class computer and data management capabilities are well suited to this task. The same types of security systems that we have long used to protect information on nuclear weapons design will ensure the secrecy and authorized access to this financial data.

After information on each bank has been developed, the data will be transformed to account for seasonal variations, normal business activities, and other relevant factors. We will develop screens that can identify unusually high currency surpluses at individual banks. More sophisticated screens will indicate possible illegal financial activity. Once suspected illegal activities are identified, financial investigations as to ownership can begin. This phase will involve many federal agencies and financial institutions. Los Alamos will maintain the secure data base for those agencies to facilitate their specific investigative needs.

Explosives Detection

As recent news stories tragically indicate, terrorist bombings continue to threaten societies around the world in several arenas. Air travel remains a major target. The Federal Aviation Administration is the lead agency in the United States for developing technologies that can detect explosives. For each of the past three years, the FAA has evaluated as many as twenty new concepts of screening passengers, baggage, and bulk cargo for concealed explosives.

In 1986 a research team that included Los Alamos personnel presented a rationale for the detection of bulk explosives based on several low level nuclear techniques used in tandem. By using several techniques together, it is possible to minimize false alarms while achieving a high level of detection. The techniques include thermal neutron activation, fast neutron activation, the associated particle technique, nuclear resonance absorption, and photonuclear activation. From the technical point of view, these nuclear-based techniques represent the most comprehensive and feasible approach for

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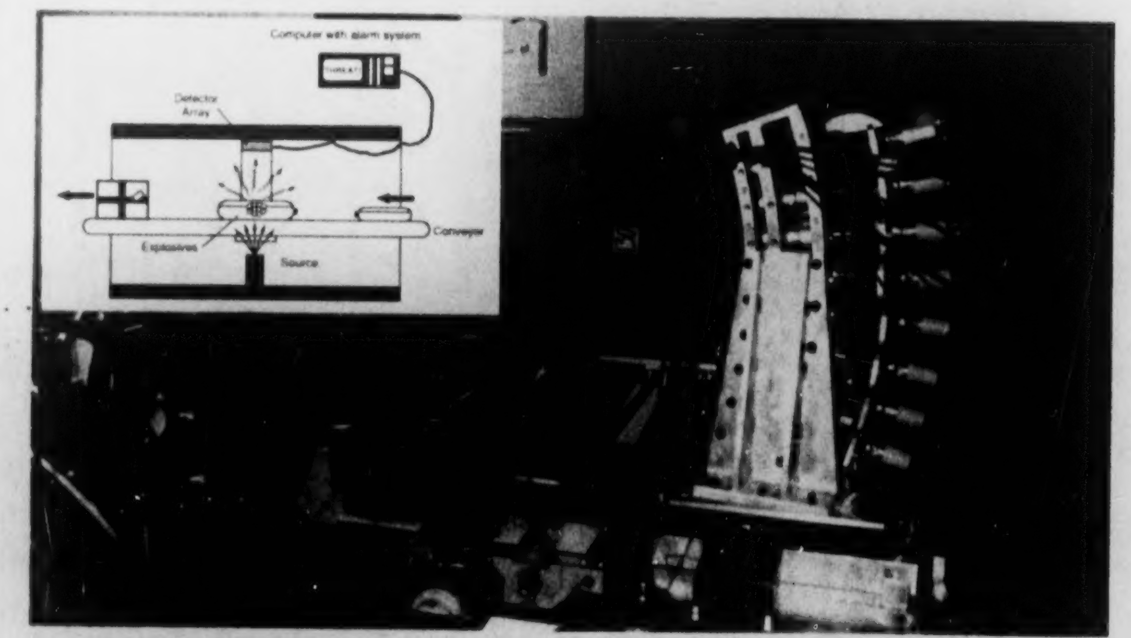
ADVANCED NEUTRON SYSTEM FOR DETECTION AND IMAGING OF EXPLOSIVES


Computer with alarm system
THREAT
Detector Array
Explosives
Source
Conveyor

meeting the criteria of accuracy in detection, minimal number of false alarms, and large volume of traffic with no significant environmental on health risks.

Nuclear-based detection techniques probe the screened items with penetrating radiation, notably neutrons and protons without causing any material damage. The probes interact with materials in the items, most notably nitrogen which is present in high-percentage weights and densities in commercial and military high explosives, and emit high-energy gamma-ray products. An array of detectors positioned near the items being screened senses the reaction products. The characteristics of these reaction products are used to determine the presence or absence of an explosive.

The thermal neutron activation system is the first truly automated explosive detection device operationally tested on airline baggage and cargo. The first commercial systems manufactured by SAIC have performed well in early tests and now being prepared for deployment. FAA plans to use the units at high-risk, Category X airports in the United States and possibly at one or two foreign airports used by U.S. carriers. As technical consultants to the FAA, Los Alamos has played an important role in the thermal neutron analysis (TNA) development program from its inception. This has included critical technical input, program reviews, and material support, such as alternative detectors and neutron-moderating materials. Efforts to refine the nuclear-based system to reduce the false alarm rates will continue.

In the past three years, Los Alamos has demonstrated the feasibility of a new and promising explosives detection technique based on the property of nuclear resonance absorption. In collaboration with other scientists, two independent methods based on this technique have been successfully demonstrated in the laboratory. These methods have the potential to detect and image the threat-quantity of explosive suspected of bringing down Pan Am Flight 103. The technique has received strong recommendations for continued support from the Presidents Commission on Aviation Security and Terrorism and the FAA has agreed to support the development of a feasibility prototype for airport testing over the next three years.

The same types of techniques used to detect explosives could be used to detect illegal drugs in large cargo containers. The scientific and engineering challenge will be to develop probes sensitive enough to detect bulk drugs, which are similar in physical features to other cargo contents, and yet to minimize nuisance alarms.

Fingerprint Detection

Fingerprints have long been a staple of scientific crime prevention in the 20th century, but they cannot be detected on all surfaces or materials. The Universal Process for Fingerprint Detection developed at Los Alamos recently made it possible to detect latent prints on a wider variety of surfaces than ever before. John Piper, an official of the U.S. Secret Service, recently hailed it as "one of the five top developments in the fingerprint field" in the past 100 years. It is a simple and inexpensive process, yet much more sensitive and safe than other processes on the market.

In the Universal Process, the object with fingerprints is soaked in an acidic colloidal gold solution. The colloidal gold binds to the protein in latent prints; bathing the object in silver solution for a few minutes makes the silver adhere to the nucleation sites created by the bound gold. Even though the process uses gold and silver as the primary active agents, it is inexpensive. The solutions cost about 25 dollars per liter. The result of the process is a permanent, well-defined print that up to now has not been recoverable.

The Universal Process improves on other methods, such as fingerprint powders, ninhydrin sprays, Super Glue, and argon lasers, because it can detect faint prints on surfaces on which conventional methods did not work. The process works equally well on porous and nonporous, light and dark, and adhesive surfaces, many of which would not hold fingerprints for detection by conventional methods. The adhesive detection ability is especially important in drug detection, because drug dealers often wrap their drugs, money, and bombs in adhesive tape. Instead of needing two or more of the other processes, law enforcement officials can use the Universal Process to detect prints on all three surfaces with one application. The process, resulting from basic research in molecular biology, might also be used to detect protein gene products responsible for the expression of genetic diseases, such as Huntington's chorea and cystic fibrosis.

EDUCATION

Although U.S. universities are the envy of the world, we have grave concerns about the K through 12 educational system. Especially alarming is the lack of interest in science and mathematics among our young. The U.S. technological position is threatened by the shortage of scientists and engineers projected for the next century and, even more so by the lack of general scientific literacy of our populace. Of particular concern is the decrease in U.S. nationals in graduate science and engineering schools. A full 55 percent of graduating engineering PhDs from U.S. universities are foreign nationals. We must make a special effort to attract minorities and women into the scientific and engineering fields because they represent the greatest pool of untapped U.S. talent.

The Department of Energy constitutes one of the largest scientific and technical workforces in the world. It employs more than 85,000 scientists, engineers, and technicians (of which approximately 6,000 are employed at Los Alamos). Without a continuous and adequate supply of technical personnel, DOE cannot assure the success of its programs. DOE has long understood that fact and therefore has a long history of formal support of education.

In a recent directive, Secretary Watkins vigorously proclaimed that it is department policy to support science, mathematics, and engineering education. He further stated that while this support was intended to take many forms, it should include the significant resources of the Department and its federal and contractor employees. It is therefore appropriate for Los Alamos to bring its significant resources of manpower and capital to support science education.

For many years, Los Alamos has actively supported undergraduate, graduate, and postdoctoral students in its various programs. Typically, Los Alamos hosts more than 1000 college students and postdoctoral appointees each year, most of whom spend at least the summer at Los Alamos. In addition, programs serve students and teachers in grades 4 through 12, touching thousands of individuals in the course of a year. (Some of these programs are targeted at New Mexico residents, and others are available to students and teachers throughout the country.) The Laboratory also sponsors programs that provide financial support and summer and part-time employment specifically for minority students and women earning degrees in the sciences.

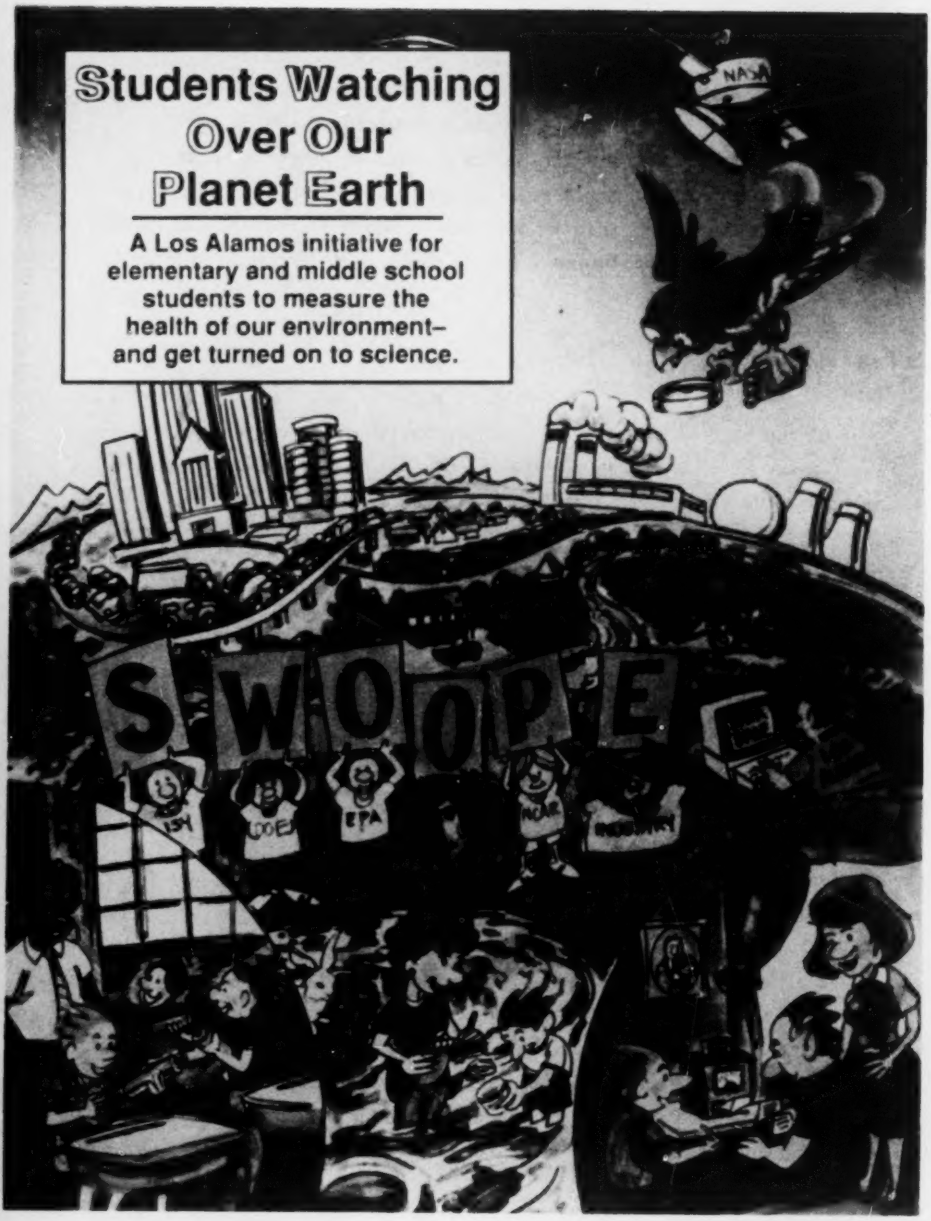
I will feature just three of our educational initiatives at Los Alamos.

SWOOPE

Los Alamos National Laboratory recently developed a program for a national project in science education. This project called SWOOPE (Students Watching Over Our Planet Earth) was launched during the twentieth anniversary of Earth Day last April. We believe that our country will not be able to deal successfully with the far-reaching global issues that are inherently technical in nature if we do not have a continuing supply of young scientists moving into universities and laboratories. A national science project like SWOOPE could help point our children and their parents in the direction of scientific literacy.

The purpose of the project is to stimulate elementary and middle-school students throughout the country to actually "do" science by gathering data on the environment that are of interest to their communities and their nation. The data would be placed in a national database and made available to all citizens and agencies.

A major goal of this project is to encourage both teachers and students to use the provided materials in their own imaginative ways but to record their investigations in a scientific manner, as their data will be included in national statistics. Another goal is to interest more students in pursuing careers in science by "catching" their interest and giving them some skills before high school. A third goal is to produce an informed citizenry -- one that is scientifically literate and able to make informed decisions about technical issues because it has been educated through active participation. Finally, the idea of funneling all this information into a national database accessible to the entire public is one that can benefit teachers and students, institutions of higher learning, and research agencies. It can fulfill one of the DOE's goals of involving the national laboratories as national resources in science education.



Students Watching Over Our Planet Earth

A Los Alamos initiative for elementary and middle school students to measure the health of our environment–and get turned on to science.

NASA
SWOOPE
ISM
DOE
EPA
NCAR
INDUSTRY

Educators have emphasized that two of the factors that can help make science education more interesting and effective are appropriate motivation and "hands-on" experience. The SWOOPE project focuses on energy-related or environmental concepts of current nationwide concern -- a subject that students identify with strongly. Specifically, Los Alamos would develop a variety of Discovery Kits to complement those already available in the educational community to guide the teachers and students in a meaningful exploration of their environment. Each kit would be centered on one concept (for example, nitrate impurities in water, radon in homes, or the ultraviolet radiation reaching the Earth's surface).

The contents of each Discovery Kit would include

- training materials for the teachers that explain the background and the science related to the concept, as well as step-by-step instructions in the safe use of the kit,
- similar materials for the students written to their level, and
- a simple, low-tech but quantitatively sound and relatively inexpensive device that would be used to gather data on the phenomena of interest.

After using the Discovery Kit materials with their teachers and learning how to gather data systematically, the students would be encouraged to explore their neighborhood and home environments, keeping track of when and where the observations were made. For this purpose, students would keep a field notebook and be legitimately involved in the scientific process of taking, recording, reporting, analyzing, and evaluating data.

In the classroom, data could then be compiled and discussed, with anomalous results rechecked. The teachers play a key role in ensuring that the data are accurate. The teachers also help plan and guide cooperative classroom projects as well as nurturing ideas suggested by particularly enthusiastic students. Because many teachers are themselves not comfortable with science, the instructional materials would provide clear and full information about the concept and show the teachers how to collect and analyze data, including all pertinent safety precautions. Hands-on workshops for teachers would also be developed to supplement the written materials.

The resulting data would be returned to Los Alamos and entered into a national database. A follow-up report from Los Alamos would be sent, perhaps quarterly, to each class to strengthen the feeling of a unified effort by our country to appraise the state of the environment. Statistics in the report would allow the students and teachers to evaluate their own work by comparing local and national results and predicting future trends. The report could also offer positive ideas for local and community action to help rectify problem areas when possible.

An important step in reducing the fear of science would be to show our children -- and even some of our scientists -- that simple, careful studies can play a significant role in modern science. A symbol of this relationship and a possible logo for the SWOOPE Project is a hawk gliding protectively over the Earth while children below gather data.

This summer teachers and scientists have come together to develop the first prototype Discovery Kits. The first two kits that have been developed will be used to assess the radioactivity of the environment and the degree of pollution in our water supply. This year these kits will be tested in fifteen different schools in three separate school districts in New Mexico in New Mexico (Albuquerque, Las Cruces, and Santa Fe) and then modified if necessary before distribution on a state-wide basis. Our intent is to develop a broad national program in which the students of the nation actually assess the "state of the environment" during the mid-1990s. DOE is funding our pilot program; a national program will require involvement by a number of federal agencies.

Waste Management Education Research Consortium

On July 26, 1989, Secretary Watkins announced approval of the New Mexico Waste Management Education Research Consortium (WERC). The Consortium includes both the Los Alamos and Sandia national laboratories and the New Mexico State University, the University of New Mexico and the New Mexico Institute of Mining and Technology. WERC is the nation's first waste management education and research program that provides an integrated approach to the increasingly critical need for efficient and safe disposal of hazardous, solid, and radioactive waste materials. Among its chief objectives are

1. To develop technologies and educational programs to solve problems associated with hazardous waste management;

2. To provide an authoritative source of waste management information and training for waste management professionals.

In its first year of operation WERC received approximately $5 million in funding from the DOE with which it has developed environmental degree programs that share the educational expertise available at the different main campuses. WERC has also used this funding to support joint research linking the universities and laboratories. This year a total of 27 research proposals received funding amounting to a total of $1.7 million. Although WERC is a consortium between universities and DOE laboratories, all funds go to support the university activities.

Teacher Enhancement Program

In FY91 Los Alamos and Sandia plan to develop and implement a teacher enhancement program for middle-school teachers in the rural areas of New Mexico not currently served by existing Laboratory programs. Fifty teachers of grades 6, 7, and 8 (25 at each laboratory) will participate in an intensive three-year training program in science, including a three-week summer institute, three follow-up academic year workshops, and visits to the classroom by program staff. During the three-year program there will be an exchange of teachers between sites to increase exposure to the different resources at each laboratory. In addition, each teacher will be required to establish a New Mexico Mathematics Engineering Science Achievement Program (MESA) chapter for 10 students in his/her school. Participating teachers will receive training on how to establish a MESA chapter and will be compensated for their work in establishing and maintaining the chapters. Students participating in the MESA program will be encouraged to pursue academic preparation for college through a suggested core curriculum that includes four years of science and math through trigonometry. A parent support organization must also be formed and sustained to meet New Mexico MESA's program requirements.

NATIONAL SECURITY/DEFENSE

With many aspects of the Soviet threat rapidly diminishing and the Warsaw Pact essentially dissolved, must the United States continue to rely on nuclear deterrence? Do we still need nuclear weapons, and specifically do we still need nuclear weapons research, development and testing (RD&T)? The public is so happy to see an end to the Cold War that it has little concern about these matters now. Democracies as a rule have a difficult time remaining "on alert" for decades. The public wants a peace dividend.

The federal government, however, has the responsibility to deliver a lasting peace as the first and foremost peace dividend. The Constitution reminds us that the federal government must provide for the common defense of its people. It cannot delegate that responsibility. It cannot gamble it on the emotions of the moment.

There is no question that the remarkable geopolitical events of the past year have dramatically altered our defense needs. We, as a nation, must take this golden opportunity to build a new security strategy that will be as successful as our policies of the last 45 years, but less demanding of national resources and with even smaller risk of global war--either nuclear or conventional. However, we cannot be careless and drop our guard too far. Clearly, the intentions of our adversaries have changed so much that some find it difficult to tell who the enemy is. Intentions, however, can change rapidly; capabilities don't. The Chairman of the Joint Chiefs of Staff, General Colin Powell, recently reminded a National Press Club audience that "Soviet nuclear power is their undisputed claim to superpower status. They won't give it up. That's an enduring reality that we must never forget. In return we must ensure that our strategic nuclear forces -- all three legs of our triad -- are never second best. This is our single most enduring defense need."

Nuclear Weapons Research Development and Testing

The DOE nuclear weapons laboratories have played a crucial role in national security for almost half a century. Los Alamos was central to the Manhattan Project and the biggest technological surprise of the century: the atomic bomb's million-fold increase in explosive power over conventional explosives. It ended World War II and changed the course of history. Since that time the laboratories have had the responsibility to provide the nuclear weapons technology required for deterrence and to explore the frontiers of science and technology to prevent our adversaries from surprising us technologically.

The laboratories have been successful. Their nuclear weapons have not been used again. Deterrence worked because it was credible, both in the eyes of our leaders and our adversaries. This credibility does not rest on any technical knowledge on part of the national leaders. It rests on assurances given to those leaders by scientists and engineers, and this assurance requires that they have credibility with their leaders. This confidence comes from the technical expertise we call nuclear competence. This competence has carefully evolved at the DOE nuclear weapons laboratories over the past forty-eight years and will be required as long as there are any nuclear weapons at all. To retain nuclear competence it is essential to retain the human expertise that makes up the nuclear weapons RD&T program. This expertise cannot be found anywhere else except at the three nuclear weapons laboratories; there are no university or private industrial sources.

To understand the continued need for nuclear competence even in today's world, one has to understand the roles that the laboratories and the weapons RD&T program play in nuclear deterrence. Nuclear competence encompasses every facet of research, design, development, and oversight of production. Additionally, it concerns surveillance of the stockpile, transportation of nuclear weapons, safety, security, the safeguarding of special nuclear materials, responding to accidents or terrorists, assessing foreign intelligence including Third World nuclear proliferation, and providing technical analyses for arms control agreements. The laboratories have all of these responsibilities under the weapons RD&T umbrella. Nothing is delegated except the custody of the weapons in stockpile. I hope that I have made it clear why weapons RD&T is crucial. It represents our ability to deal with all facets of nuclear weapons, and it supports our nuclear competence.

The dramatic changes in the world provide us now with a great opportunity, a significant reduction in the world's armament burden, conventional and nuclear, while at the same time increasing national security. We are excited by this opportunity and prepared to turn our priorities to building down the U.S. nuclear arsenal. This process must be done carefully to protect the nation's security and preserve global stability.

In fact, recent world events have already significantly changed our weapons RD&T priorities but have not diminished our responsibilities. Enhanced safety, security, survivability, command and control are receiving greater emphasis. We are mounting a major initiative to incorporate features of enhanced nuclear weapons safety into the intrinsic design of the warheads, so we can rely less on operational safeguards. Warhead manufacturing is increasingly dominated by issues of waste minimization, waste management, and environmental impacts, which are issues related to nuclear weapons design and could be partially ameliorated by design trade off.

Continued research and development will also address developing a better fundamental understanding of physical phenomena that occur in nuclear weapons. Nuclear fission and thermonuclear weapons are so complex and insufficiently understood that we cannot predict their behavior from first principles or by computers alone. Futhermore, the conditions that exist during a nuclear explosion, with temperatures and pressures similar to those in the interior of stars, cannot be simulated adequately in the laboratory. Hence, the design process is an iterative one involving theory, computer modeling and calculations, nonnuclear laboratory tests, and underground nuclear tests. Nuclear tests are essential in resolving serious gaps in our theoretical models. In a similar fashion, nuclear tests provide the final word on warhead engineering and packaging of components. The subtleties of many engineering changes on warhead design are often more difficult to model and predict than physics design changes. Nuclear tests also help assess the effects of stockpile conditions such as aging and stockpile-to-target environments, including potential effects of hostile nuclear environments, and concerns about nuclear safety.

A better understanding of weapons behavior and continued research into all facets of nuclear weapons will allow us to help the build down of the nuclear arsenal and to protect us against revolutionary discoveries on the part of our adversaries that may render our weapons ineffective and undermine deterrence and the nation's security.

Currently, the Los Alamos budget for the core weapons RD&T program is approximately $230 million. This sum represents a loss of approximately 25 percent of the nuclear weapons expertise over the past six years. I am convinced that additional cuts would undermine nuclear competence and the cornerstone of this nation's security.

Broader Responsibilities for Defense

The nuclear weapons RD&T program not only continues to serve the nation well in helping to maintain deterrence, but it has provided the springboard for much broader defense contributions. The broad charter, the vertical integration, the applications orientation, and the strong support for scientific underpinnings have supported a broad science and technology base at the three nuclear weapons laboratories. This base has allowed them to contribute to other pressing defense needs.

The laboratories are helping the DOE weapons complex with its currently vexing problems such as materials availability, environmental cleanup, and modernization of the complex. Currently the supply of tritium is a critical and urgent problem. Los Alamos is helping with both the restart of the Savannah River Reactors that produce tritium and the New Production Reactors. Our principal role is to provide technical safety analysis.

The United States does not require a new plutonium supply today. However, the ability to recycle production scrap and the plutonium from warhead returns is crucial. The Rocky Flats plant, which handles most of the plutonium work, is currently shut down. Los Alamos is providing technical assistance in plutonium chemistry and processing to aid in the safe restart and effective operation of these facilities.

The projected cost of environmental cleanup at the DOE weapons sites is enormous. As I stated earlier, the laboratories are prepared to help DOE do the cleanup smarter, cheaper, and faster through the application of state-of-the-art environmental R&D and technology transfer to industry. Similarly modernization of the complex cannot be relegated to bricks and mortar. The complex of the future will have to be smaller, more efficient, safer, and environmentally acceptable. Again, the laboratories stand prepared to help with technological solutions.

The nuclear weapons laboratories also continue to contribute in the areas of arms control, strategic defense research, and advanced conventional munitions and concepts.

Our arms control activities consist of technical expert support for U.S. negotiators and the development and deployment of verification technologies. Los Alamos's work in verification extends over more than a quarter-century, dating from its development of satellite-borne sensors for verifying compliance with the 1963 Limited Test Ban Treaty and its ban on nuclear tests in the atmosphere, in outer space, or under water. The Laboratory has also developed instrumentation and has trained inspectors for nuclear materials monitoring in support of the 1967 Nuclear Non-proliferation Treaty.

At the present time, the Senate is holding hearings on ratification of the Threshold Test Ban Treaty and Peaceful Nuclear Explosions Treaty, signed in 1974 and 1976 respectively, to limit the yields of underground tests, but only now considered acceptable for ratification after the incorporation of new verification protocols. The successful negotiation of these new protocols has relied to a large extent on the technique of hydrodynamic yield measurement of underground tests, using the CORRTEX (Continuous Reflectometry Radius Versus Time Experiment) system developed over the past 14 years at Los Alamos.

In addition to the two nuclear testing treaties, at least five other potential arms control agreements are at various stages of consideration: strategic arms reduction, chemical weapons production and stockpiling, conventional forces in Europe, short-range nuclear forces, and defense and space talks.

These treaties will demand additional technologies for verification and safeguards. We believe that Los Alamos can execute a more broadly based verification and arms control technology program. We have capabilities in the technology required for the support of future arms control agreements in strategic and theater nuclear weapons as well as for improved methods of detecting nuclear explosions.

In addition to the CORRTEX technique, other examples of our contributions are advanced verification technology using infrasound and ionospheric monitoring, and programs supporting on-site monitoring requirements resulting from the Intermediate-Range Nuclear Forces Treaty and the Strategic Arms Reduction Talks. Monitoring and verification of activities in outer space may become a major effort in the future. We are beginning to apply our experience gained in the Limited Test Ban Treaty monitoring program to this challenging new problem. Another example is the ultrasensitive detection of chemical and biological threat agents. In this area, we expect to establish programs to facilitate verification of the Chemical and Biological Warfare Treaty introduced at the 1985 Conference on Disarmament in Geneva. Likewise, we are developing programs for radiation detection and imaging for possible applications in scenarios that would limit or control nuclear warheads. Much of the technology for these programs was developed initially under the Nuclear Safeguards Program supporting the International Atomic Energy Agency.

Los Alamos has been involved in the scientific research and technology foundations of strategic defense for many years. The neutral particle beam (NPB) program is the Laboratory's top-priority nonnuclear concept for the Strategic Defense Initiative (SDI) and the nation's lead SDI concept for midcourse target discrimination. The NPB concept stems from our strong accelerator expertise and considerable experimental and computational physics capabilities. An integrated program with extensive industrial participation is currently in progress at the Laboratory to address all the major components of an NPB system. Under the sponsorship of the U.S. Army, a partnership has been forged to expeditiously transfer the key accelerator technology to the private sector.

We recently demonstrated the feasibility of operating an NPB in space in an experiment called BEAR (beam experiments aboard a rocket). On July 13, 1989, BEAR was successfully launched on a suborbital flight from White Sands Missile Range, providing NPB researchers with important information on the interactions of the emitted beam with the spacecraft and the space environment. Although Los Alamos provided the overall technical direction for the experiment, we also teamed with industry to provide critical components for BEAR.

Like the NPB program, the free-electron laser (FEL) program has been in existence at Los Alamos for some time. It is aimed at providing the potential of speed-of-light defense against ballistic missiles, especially if the threat comes from faster burning missiles or bunched launchers. We have pioneered the application of radio-frequency acceleration technology to accelerate electrons to high energies with subsequent conversion to coherent optical radiation. We have successfully demonstrated the highest oscillator extraction efficiency, achieving 4.5 percent in the conversion of electron-beam energy to 10 micron light with an average power of about 15 kilowatts. We have also shown the widest tunability (9-45 microns). In a 1989 cooperative effort with Los Alamos, Boeing Aerospace Company also obtained a high conversion efficiency (1 percent) with its FEL at optical wavelengths (0.6 microns) and at an average power of about 1 kilowatt.

We developed high-efficiency, high-brightness, photoelectric electron-beam generators; developed and benchmarked a dynamic FEL system simulation code; and demonstrated a 5-percent extraction efficiency (electron beam to light) in good agreement with the simulation code.

In 1989, we also demonstrated electron-beam brightness levels (for short pulses) in a new FEL facility called HIBAF (high-brightness free-electron laser accelerator), exceeding the levels required for the Army's Technology Integration Experiment. For this experiment, the Laboratory, teamed with the Boeing Aerospace Company, has been selected to develop an FEL based on a radio-frequency linear accelerator to explore whether FELs can scale to the performance levels required for SDI applications. For this purpose, the Army's Strategic Defense Command is building a ground-based FEL facility at White Sands Missile Range, New Mexico.

To date we have demonstrated that directed-energy concepts are considerably stronger technological strategic defense candidates than previously imagined. We continue to explore the NPB and FEL technologies for other defense and civilian applications. Two civilian applications, accelerator-based transmutation of nuclear waste and free-electron laser photolithography, were described above.

The Laboratory has made strong contributions in advanced conventional munitions and related military hardware using our broad technical base in high-explosives and materials, our considerable experience with working in multidisciplinary programs, and our use of large-scale computer simulations and advanced diagnostics capabilities to help solve complicated problems. Because of these capabilities, nonnuclear weapons work at the Laboratory has grown in recent years. As already mentioned in addition to munitions and materials for the conventional battlefield, conventional defense technology includes activity in counternarcotics/counterterrorism; modeling and computer software for command, control, communication, and intelligence and war games; and maritime and undersea weapons, sensors, and communication.

Clearly the defense contributions we can make to DoD applications are numerous. With the decrease in the overall defense budget it will be imperative for the nation to leverage its resources even more. The nuclear weapons laboratories can provide a strong technology base for the DoD as the threat changes and the budgets decrease. They could support revolutionary approaches to surveillance (such as distributed surveillance), information processing, smarter weapons, nonlethal weapons (such as electromagnetic weapons), advanced simulation and modeling, and maritime warfare.

Los Alamos and its two sister laboratories offer a wide range of scientific and engineering expertise. We have smart people who think about the defense implications and applications of the latest scientific breakthroughs in an environment where they can effect solutions. That is one of the best insurance policies that this nation can hold in a world that is changing so rapidly.

ENHANCING OUR CONTRIBUTIONS TO THE NATION

Clearly the defense role of the laboratories must continue to be strong as the nation continues its vigilance. Maintaining first-rate scientific institutions and retaining the best scientific talent will be imperative. Strong civilian R&D programs that enhance the multiprogram nature of the laboratories will help to preserve their strong defense role. There are other factors, discussed below, that are also important to excellence at the laboratories.

Continued Support for Basic Research

The United States continues to lead the world in basic research largely on the strength of its research universities, which are the envy of the world. The federal government's role in supporting basic research is crucial and most appropriate. The nation must continue to support university research, especially in the principal investigator mode. Such research gives rise to scientific breakthroughs that form the foundations for new technologies and markets. It also provides the training ground for the next generation of scientists and technologists.

Basic research at the DOE laboratories is also critical. First, the department has a distinct basic research mission in areas such as nuclear and particle physics. For many years it has operated large research facilities such as accelerators, synchrotrons, reactors, and electron microscopes as user research facilities for the academic and industrial communities. Many of these resources are provided at the DOE single-purpose laboratories.

Basic research at the multiprogram laboratories has the additional benefit of laying the foundations for the technological projects I discussed earlier. This research is a very important leverage for the federal support. Without the basic research support, the technological ideas will wilt and not keep pace with society's needs.

Especially critical to the DOE laboratories is the concept of laboratory-directed R&D (LDRD). Through these programs, the Laboratory directors select research and development projects that, in their judgment, are of outstanding quality and strengthen the capability to address emerging and future needs. Discretionary funding for innovative research has proven invaluable in contributing to national needs in both the civilian and defense areas. Yet, these LDRD programs are directly threatened by language currently in the FY91 House Energy and Water Development Appropriations bill. Elimination of these programs would virtually destroy the capability of the laboratories to respond to future national needs in a timely and effective way.

The most important function of LDRD funding is to provide for the long-term vitality of the laboratories. Today, the federal government is almost alone in supporting long-term science and technology. U.S. industry, for the most part, has succumbed to the quarterly balance sheet. It would be most unfortunate to jeopardize the future of institutions chartered with developing long-term science and technology as a major pillar of national security. Prestigious external review panels have understood that LDRD is critical to the long-term vitality of all multiprogram laboratories and have strongly recommended that DOE continue to allow independent LDRD programs representing 5 to 10 percent of annual funding.

Let me point out several ways in which LDRD funding helps the laboratories:

First, LDRD helps the laboratories rejuvenate their science and technology base so they can respond rapidly to changes in programmatic directions. Ongoing programs support current needs and do not generally provide this capability.

Second, LDRD helps the laboratories respond rapidly to new ideas and opportunities. The institutions do not have to wait two years for funding, the length of the cycle typical of funding agencies.

Third, LDRD helps the laboratories make good use of their talented staff. When programs start up or shut down, the directors can smoothly redeploy the appropriate employees and retain their expertise.

Fourth, LDRD helps the laboratories recruit outstanding scientists and engineers. Local decision making allows rapid action to recruit outstanding talent interested in a particular field, whereas to attract external funding support would delay recruitment and exceptional talent could go elsewhere.

Virtually all large programs at the laboratories trace their beginnings to early support from LDRD programs. The quality and productivity of these internally funded programs continues to be remarkable. At Los Alamos, the LDRD initiatives have an outstanding record of innovation and productivity. Major programs that began with LDRD support include magnetic fusion, inertial fusion, human genome research, free-electron lasers, neutral particle beams, and numerous others.

A New Paradigm of Government-Industry Cooperation

As important as basic research is, the government must extend its influence in supporting science and technology beyond basic research to turn our technological abilities into a competitive advantage. One compelling reason is that the technological abilities of competing nations are so robust that they frequently turn our ideas into applications before we do. To control the dissemination of basic research is counterproductive. We can succeed only if we retune our technological engines and do a better job of turning technologies into applications than our competitors do.

Collaboration between the U.S. government and the private sector is not new, but it is principally limited to those areas where the government is a legitimate customer, i.e. defense, space, and increasingly environmental remediation of government facilities. The areas of agriculture and biotechnology have also experienced positive cooperation. Unfortunately, such examples are rare for most other commercial markets. The inexorable realities of international competition now mandate government-industry cooperation in these markets. Such cooperation must take many forms, from macroeconomic fixes to technological ones. No single initiative will do.

I believe that the solutions must target the U.S. industrial technology base. We must enhance U.S. manufacturing knowledge and capacity to regain our industrial leadership. Industry has formed consortia under the 1984 National Cooperative Research Act to pool research resources. The government is a partner in some of these consortia, such as the highly visible Sematech initiative.

What I am proposing here is a different form of collaboration © one in which the government provides not only financial capital but also intellectual capital, namely that of the DOE laboratories. As indicated in the technical examples above, the DOE labs are capable and anxious to participate with industry on problems important to the nation. These new partnerships will be directed by industry's interest and pulled by its anticipation of market forces. It will be enhanced by the technology push of the laboratories where industry now can leverage its interest with the government's annual investment of $5 billion for R&D, with a capital investment exceeding that by several fold.

One very important push in this direction was provided by the passage of the National Competitiveness Technology Transfer Act in 1989. It removed many of the barriers for laboratory-industry collaboration and added technology transfer as a mission to the DOE laboratories. To implement the spirit of this act, industry in collaboration with the laboratories must now propose, the DOE support, and Congress appropriate funds for specific collaborative R&D projects. The projects described above, aimed at solving problems of great national concern, are clearly a step in that direction.

I have no doubt that Los Alamos and the other DOE laboratories can do a superb job in developing broad-ranging technologies important to this nation. However, for us to make a competitive difference in civilian applications, a strong link to industry must be forged.

CONCLUDING REMARKS

The remarkable geopolitical events of the past year call for a re-examination of the meaning of national security. They call for a smaller military, but not a hollow one. They clearly call for increased federal attention to enhance our quality of life-by improving our economic competitiveness, cleaning up our environment, providing clean and affordable energy, and improving the quality and cost effectiveness of health care.

For nearly half a century, Los Alamos has enjoyed excellent federal support to build one of the finest scientific and engineering institutions in the world, principally in the name of defense. We have served the nation well. We stand prepared to continue to be the guardians of nuclear competence to assure a viable deterrent to future conflicts.

We are also prepared to use our resources increasingly to solve other large, technologically complex problems facing the nation. I have provided but a few examples of our work and our ideas that address the problems of today.

Los Alamos Contributes to National Problems of Public Concern

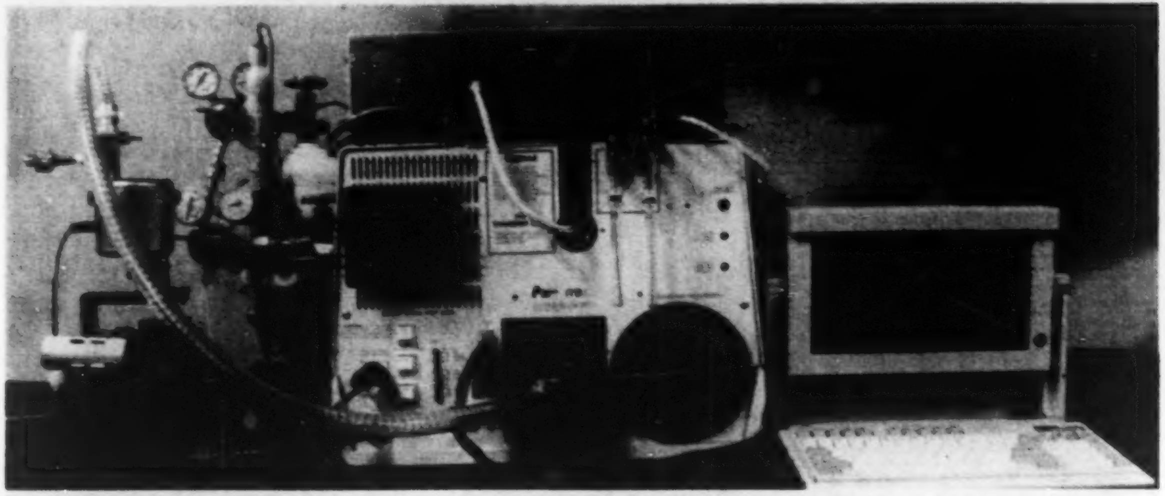
- Environmental Degradation
- Energy
- Economic Competitiveness
- Health Care/AIDS
- Drugs and Terrorism
- Education
- National Security/Defense

A new paradigm of industry-laboratory R&D collaboration is required to leverage the federal investment

IS-12/90-2506 /33

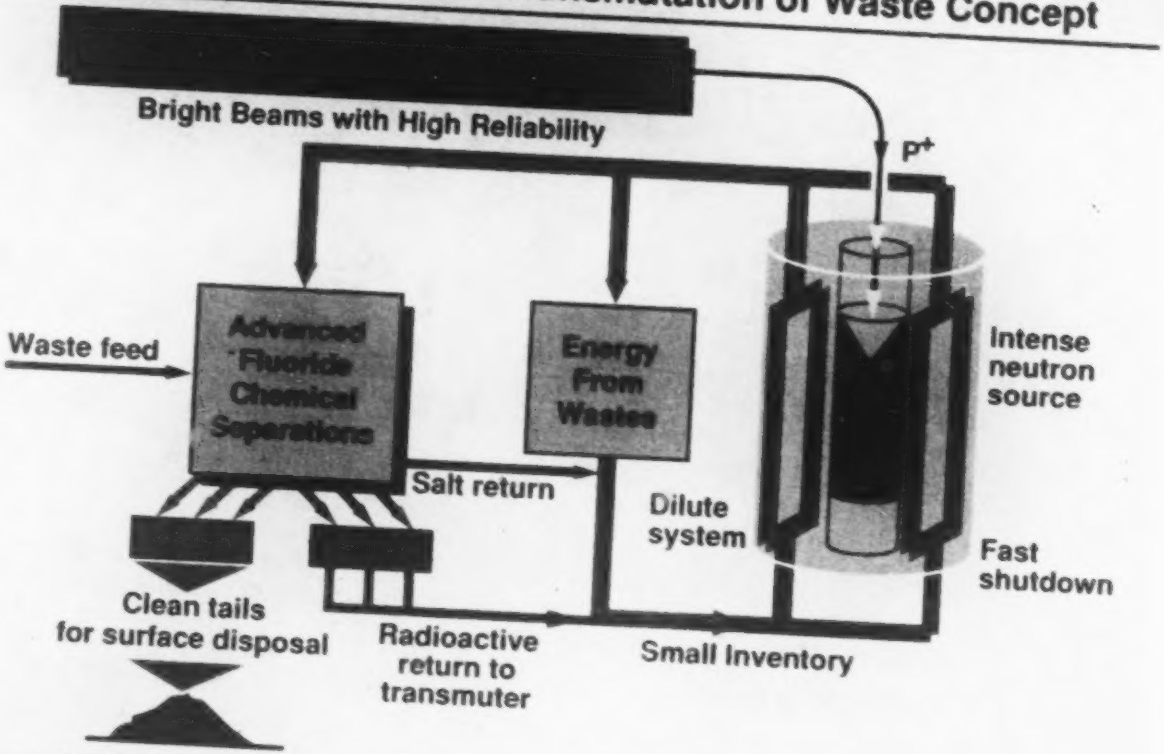
THE FIELD TRANSPORTABLE MIDGET MASS SPECTROMETER PROVIDES HIGHLY SENSITIVE ANALYSIS AT 30% LOWER COST

- Automated operation, technician operated
- Analyzes for 60 EPA regulated volatile organic compounds
- 20 minutes per sample in the field
- Sensitivity 10 to 1000 times greater than required



Los Alamos

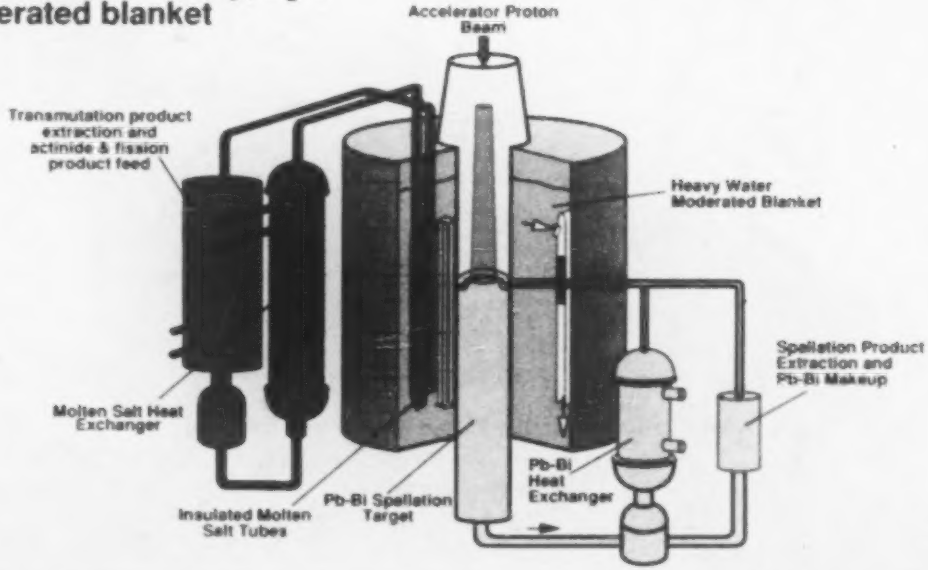
Los Alamos Accelerator Transmutation of Waste Concept


Bright Beams with High Reliability
P+
Waste feed
Advanced Fluoride Chemical Separations
Energy From Wastes
Intense neutron source
Salt return
Dilute system
Fast shutdown
Clean tails for surface disposal
Radioactive return to transmuter
Small Inventory

Accelerator Transmutation of Waste — Los Alamos

Accelerator Transmutation of Waste Design

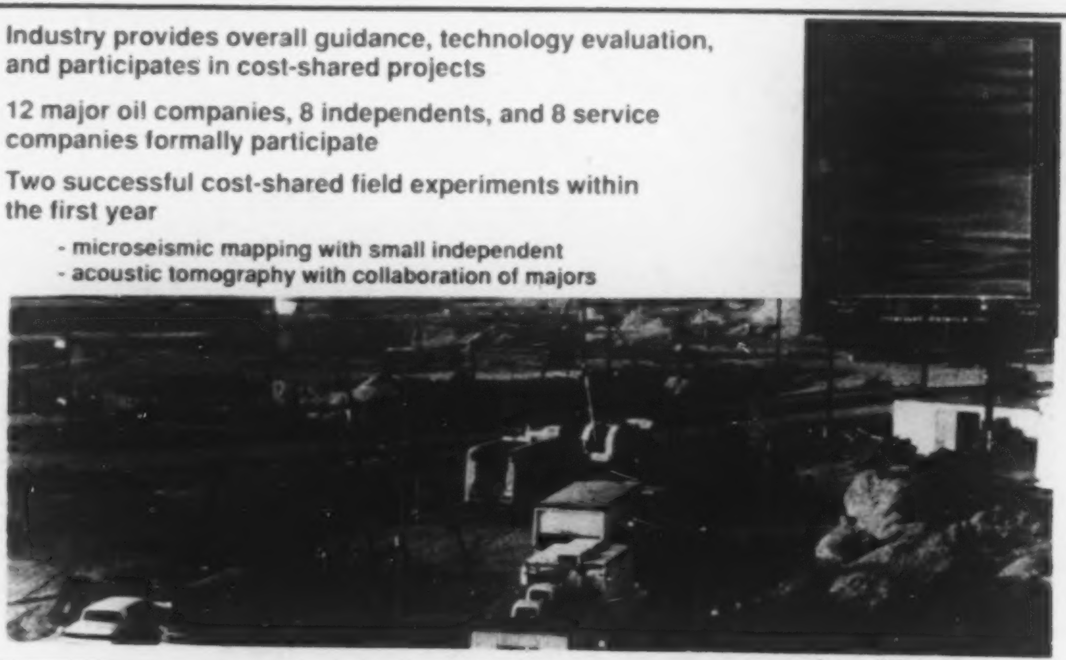
- Accelerator driven
- Lead-bismuth spallation neutron production
- Low fissile inventory, D_2O moderated blanket
- Flowing molten salt waste carrier
- Continuous processing
- Optional power production


Accelerator Proton Beam
Transmutation product extraction and actinide & fission product feed
Heavy Water Moderated Blanket
Spallation Product Extraction and Pb-Bi Makeup
Molten Salt Heat Exchanger
Pb-Bi Heat Exchanger
Insulated Molten Salt Tubes
Pb-Bi Spallation Target

IS-12/90-2510 /33

The Oil Recovery Technology Partnership allies the Department of Energy, Los Alamos and Sandia National Laboratories and the United States petroleum industry

- Industry provides overall guidance, technology evaluation, and participates in cost-shared projects
- 12 major oil companies, 8 independents, and 8 service companies formally participate
- Two successful cost-shared field experiments within the first year
  - microseismic mapping with small independent
  - acoustic tomography with collaboration of majors

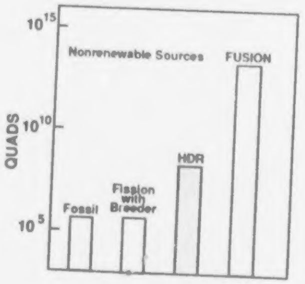


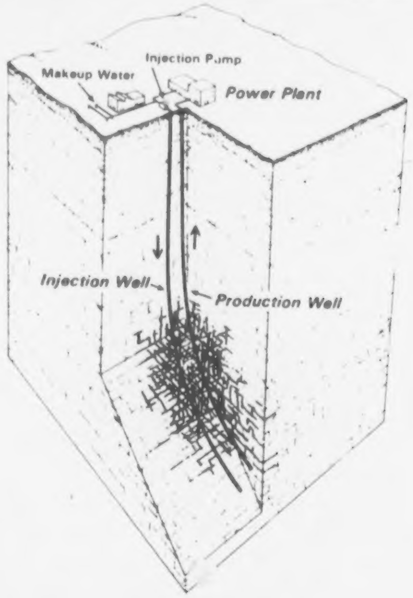
Los Alamos

IS-12/90-2509 /33

HOT DRY ROCK GEOTHERMAL ENERGY PROVIDES AN ENVIRONMENTALLY ACCEPTABLE RENEWABLE ENERGY OPTION

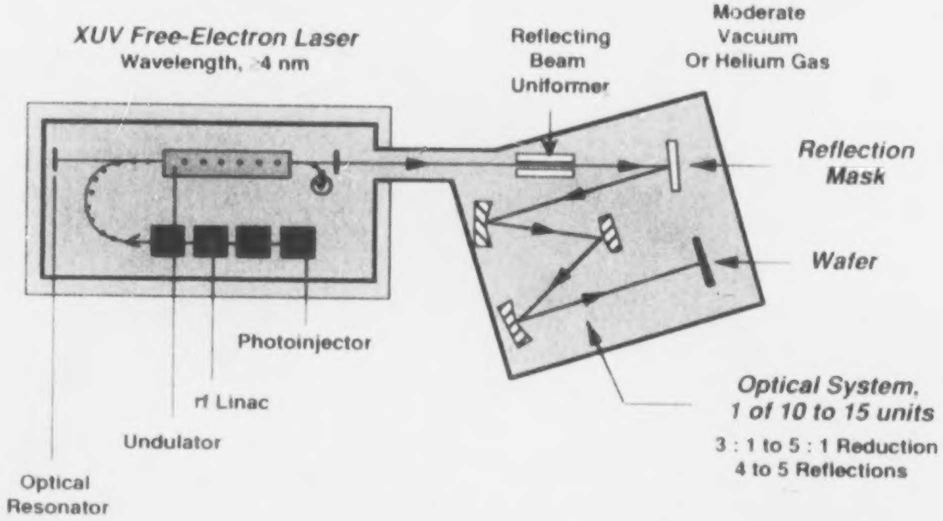
- Enormous resource base, encompassing much of the United States
- Potentially cost competitive with coal
- Potential to revitalize domestic oil and gas drilling/services industry
- Export opportunities exploiting worldwide resources




Makeup Water
Injection Pump
Power Plant
Injection Well
Production Well

Los Alamos

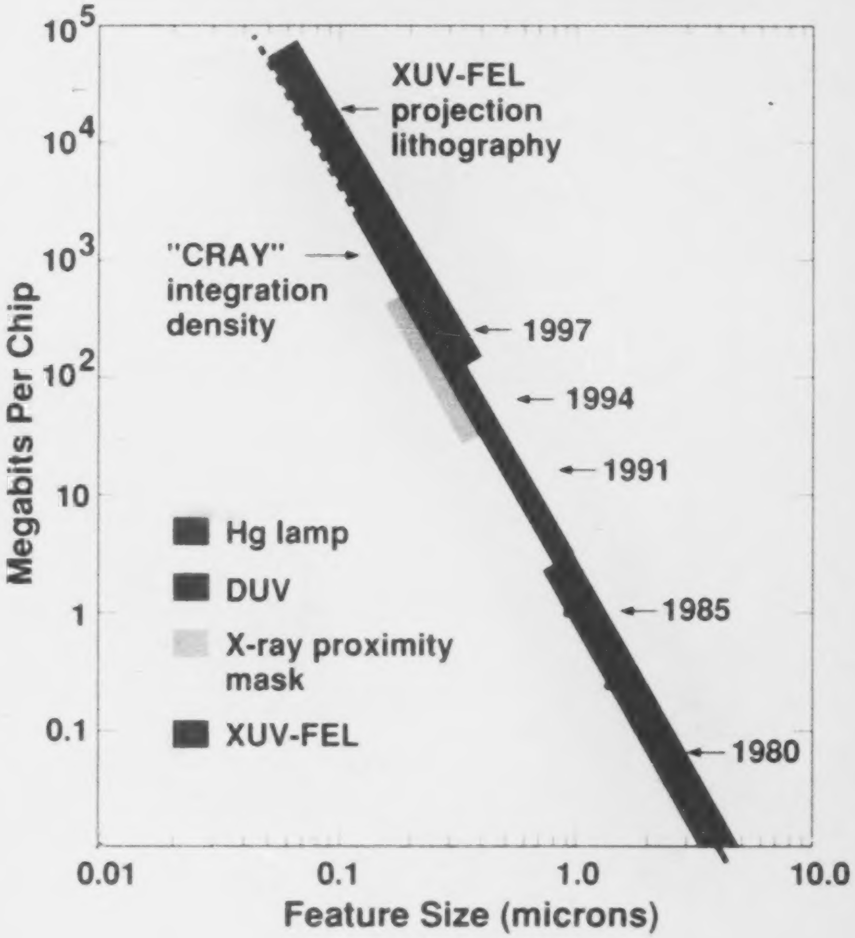
Los Alamos Approach to 0.1-μm Resolution Lithography Will Use an XUV Free-Electron Laser, A Reflecting Mask and Projection System, and Surface-Imaging Resists


XUV Free-Electron Laser
Wavelength, ~4 nm
Reflecting Beam Uniformer
Moderate Vacuum Or Helium Gas
Reflection Mask
Wafer
Photoinjector
rf Linac
Undulator
Optical Resonator
Optical System, 1 of 10 to 15 units
3 : 1 to 5 : 1 Reduction
4 to 5 Reflections

Los Alamos

IS-12/90-20128 27

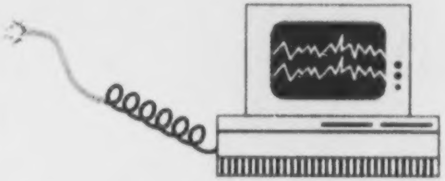
Sub-Tenth Micron Features Will Enable Ultimate Large-Scale Integration



Los Alamos

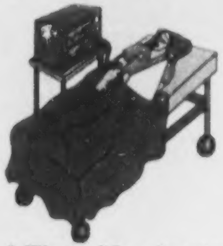
Real-Time Laser Diagnostics for Future Applications in Medicine

Smart Endoscope



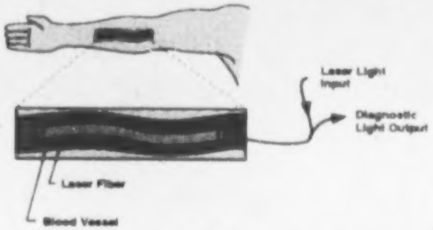
Computer Controlled Endoscope for Real-Time Detection of Cancer

Medication Monitoring



Real-Time Monitoring of Medication Levels

Blood Component Analysis


Laser Light Input
Diagnostic Light Output
Laser Fiber
Blood Vessel

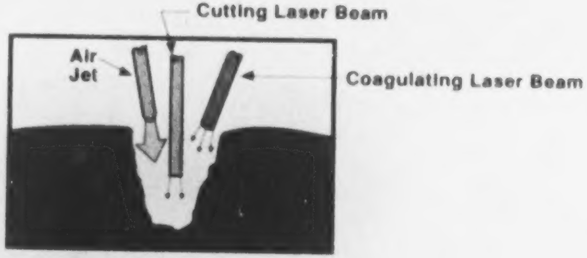
Continuous Real-time Analysis of Critical Blood Components

Los Alamos

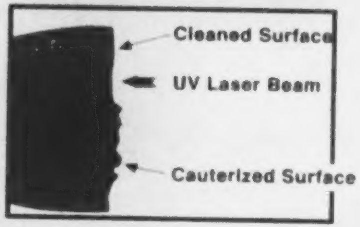
Liver Transection

- Because of the extreme perfusion of blood in the liver it now takes 6-8 hours to make one transection.
- If this time could be reduced, the regeneration of the liver could be exploited --- one donor liver could be implanted in three recipients.

Cutting Approach:


Cutting Laser Beam
Air Jet
Coagulating Laser Beam

Followed by Debridement:

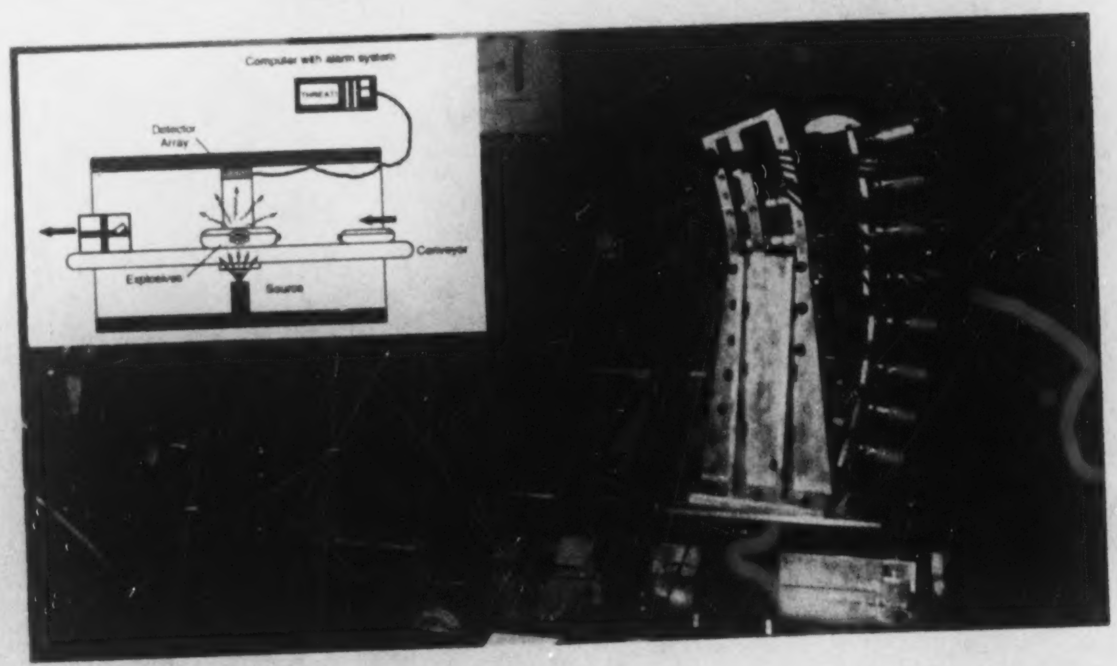

Cleaned Surface
UV Laser Beam
Cauterized Surface

The cleaned surface will regenerate more effectively than a cauterized and charred surface.

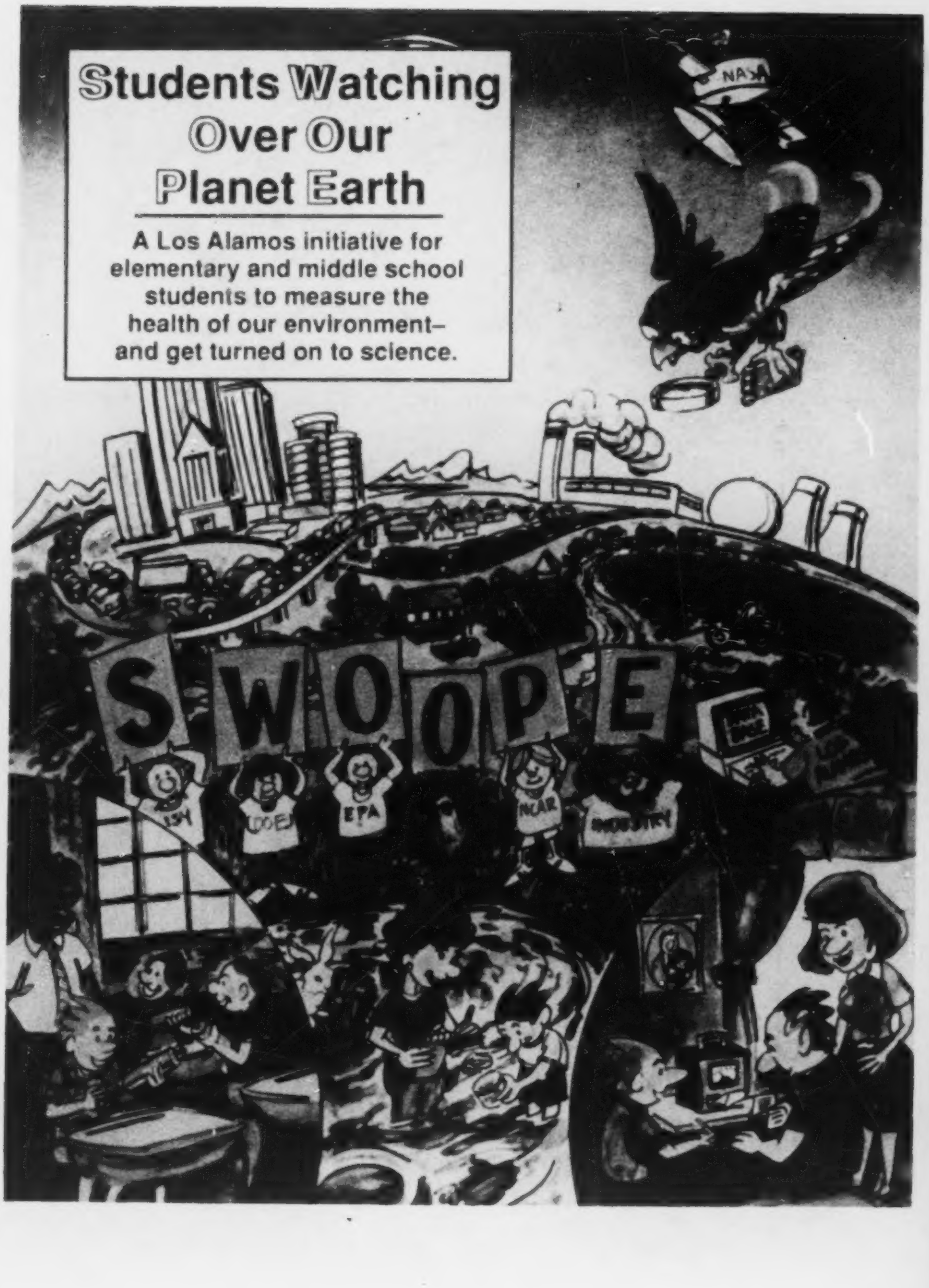
Los Alamos

IS-12/90-2511 /33

ADVANCED NEUTRON SYSTEM FOR DETECTION AND IMAGING OF EXPLOSIVES


Computer with alarm system
THREAT!
Detector Array
Conveyor
Explosives
Source

Los Alamos


Students Watching Over Our Planet Earth
A Los Alamos initiative for elementary and middle school students to measure the health of our environment– and get turned on to science.
NASA
SWOOPE
LSM
DOE
EPA
NCAR
INDUSTRY

IS-12/90-2525/ 38

Los Alamos: Science Making a Difference in the 21st Century

- We will contribute to solutions of pressing problems facing the nation,
- While maintaining the nation's nuclear competence to secure a lasting peace

Senator **Bingaman**. Thank you very much.

Let me just alert everybody, all witnesses and everyone else, that our schedule is such that we are going to have to adjourn at about 12:40 p.m. at the latest. So we will try first to go through this panel and ask very few questions and then bring on the next panel so that everybody will get a chance to testify. I just thought I would put everybody on notice that that is the plan of action at this point.

Dr. Narath, why not go right ahead.

STATEMENT OF DR. ALBERT NARATH, PRESIDENT, SANDIA NATIONAL LABORATORIES

Dr. **Narath**. Thank you, Senator Bingaman, Senator McClure, Senator Domenici. I would like to thank you for this opportunity to address you this morning.

What I would like to do in the 5 to 10 minutes that I have is to summarize for the most part some views and impressions I gained during my first year as Sandia's lab director, having spent prior to that 5 years at AT&T Bell Laboratories.

To say that this year has been exciting would be an understatement. It has also been a period during which I have become aware of some real threats to the future of the laboratory. I must tell you that I am very much concerned.

In that regard before I go any further, I would like to thank three individuals in particular for help they have offered in recent times. I am fully aware of the actions that have been taken by Senators Johnston, Bingaman and Domenici in recent times in support of the DOE defense laboratories. I would like to express my personal appreciation for the confidence that that help has expressed. I intend not to disappoint that confidence.

As you know, Sandia is a government contractor-operated national laboratory. It has been operated by AT&T since 1949 under a no-fee/no-profit arrangement. I think it is interesting to note that from the beginning AT&T chose Bell Laboratories as the model for Sandia. It is an appropriate model because of Bell Laboratories' firm foundation and research and its close ties to the manufacturing and product needs of the telephone system. It has served Sandia well as a model over the years.

Incidentally, this heritage has given Sandia a very deep understanding of the problems associated with transferring scientific know-how and technological understanding into things which serve the end user.

Like Bell Labs, our strength and effectiveness are tightly linked to our technology base. This base of technical experience, know-how and facilities has not only enabled our contributions to the weapons program but has also been a key factor in Sandia's successes in energy research and development as well as many other activities.

Incidentally, our non-defense work in fiscal year 1990 amounts to between $130 million and $140 million.

I might also mention that we are very much in sync with the Department of Energy's national energy strategy. We have directed our research and development in such a way as to be fully supportive of that strategy. For example, much of our energy work has large potential impact in the area of environmental quality. We have recently demonstrated a solar process for purifying water polluted with organic compounds. The potential impact on the water pollution problem is enormous, I believe, and the cost of the process is modest.

We are also a world leader in the management, packaging, transportation and storage of radioactive wastes, and with our close ties to the production agencies of the nuclear weapons program we are also beginning to become very innovative in waste minimization techniques for manufacturing.

The growing awareness that energy and the environment are part of a complex interrelated set of problems facing the Nation, I believe serves as a reminder that we are entering a period of rapidly evolving national priorities. We all understand that these changes are being driven by easing of military tensions around the world and dramatic reversals in geopolitical trends but also in the U.S. by budget problems, trade deficits and generally a concern over the possibility of serious economic stagnation.

I would also like to observe that while the Cold War may be less of a threat than previously, the war is not over. Defense needs will continue at some level. Perhaps more importantly, there are other challenges as well. They abound in the areas of energy supply, conservation, environment and health care, to name only a few.

I am convinced that the fundamental challenge remains the same, the preservation of national security. The composition of the threat facing us may be shifting, but the underlying nature of the challenge remains the same. It is global economic competition. It is today; it was in years past. Without economic strength, there can be no effective defense. Without effective defense, in the long run we cannot be assured of economic strength. These are interrelated factors.

I think there is a common denominator in this continuing struggle that we are facing. Whether we are dealing with defense or consumer electronics, success depends on technological superiority, not just innovation, I remind you, but the ability to bring technology to the marketplace rapidly and at low cost.

The United States can take pride in having an abundance of world class technical enterprises. We all understand that we have universities, research universities in particular, that are the envy of the world; first class industrial research labs even today; and outstanding Federal labs. I certainly include the DOE national laboratories in that list.

Somehow as a Nation we have not found a way to achieve a level of direction, focus and cooperation among these diverse segments to assure continuous U.S. economic superiority. I believe that the national laboratories can play a major role in fostering more cooperative relationships among universities, industry and Federal labs. With DOE encouragement and support and the mandate provided by the recent technology transfer legislation, the rate of progress in this direction has accelerated markedly.

At Sandia we have utilized the technology base supported by DOE's DP and BES programs to establish a rapidly-growing number of cooperative programs with industry, universities and several of the other national laboratories. Examples cover a diverse spectrum of activities such as our combustion research program at Sandia's Livermore Laboratory which is aimed at increasing the efficiency of combustion in automobile engines and other applications.

I might point out that in this area we have cooperated with a number of other national laboratories like Lawrence Livermore, Los Alamos and most recently have gone into partnership with Lawrence Berkeley Lab which hopefully will strengthen our program and enable Lawrence Berkeley Lab to mount a very significant program in combustion dynamics.

We have also been active in nonevasive monitoring methods for blood sugar to control diabetes as well as smart robots for precision machining applications.

Just last week I participated with Secretary Watkins and Senators Bingaman and Domenici in a signing ceremony here in the Dirksen Building establishing a DOE-industry consortium of U.S. specialty metals processing companies to collaborate in generic precompetitive research and development and manufacturing process control. The participating firms will work together to advance the state of their processing technologies so they can individually become more competitive in the international market. I view Sandia to be a catalyst in this interaction, providing a base of expertise in material science and fabrication engineering that it has established over many years in the weapons program.

The question was asked earlier, how do we choose among the many different directions that we can go in technology transfer. In my view we need to emphasize the creation of industrial consortia because in doing so we maintain a position that is both precompetitive as well as generic, thereby avoiding conflict of interest.

I also think we need to emphasize technologies that currently exist within the laboratories and, secondly, give preference to industries which are strategically important to the United States and are currently facing serious foreign competition.

Let me point out something that all of you understand. We have a tradition in this country of rugged individualism. But today the rugged individualists are having a very tough time. Indeed, the majority of our start-up enterprises fail or are acquired by foreign interests. And established companies are finding the competition to be more formidable than ever.

But I do not think we need an American version of MITI or some new agency. I think the necessary institutions are already in place. What we need is a new culture of teamwork and cooperation that unites industry, universities, government and the national laboratories as partners on the same team. The challenges of the 1990's are complex, technical and multi-disciplinary. In my view, the environment, energy and economic competitiveness are tightly linked as a single field of endeavor, where the national laboratories will make outstanding contributions in the future.

Thank you.

[The prepared statement of Dr. Narath follows:]

United States Senate
Energy and Natural Resources Committee

Energy Research and Development Subcommittee

Statement by

Albert Narath, President
Sandia National Laboratories

July 25, 1990

Chairman Ford, distinguished members of the committee, thank you for this opportunity to speak with you. I am Al Narath, president of Sandia National Laboratories.

As you know, Sandia is a government-owned, contractor-operated national laboratory that has been operated by AT&T on a no-profit, no-fee basis since it was urged to do so by President Truman in 1949. At the time, it was felt that The Bell Laboratories model, with its foundations in applied research and its close ties to the manufacturing and product needs of the telephone system, represented the most desirable model for management of the laboratory. Today, as in the past, we believe that Bell Laboratories continues to be the appropriate model for Sandia. We have adopted the Bell Laboratories operating style in the manner in which we achieve the integration of scientific creativity and engineering innovation to yield comprehensive solutions to technically challenging problems. Like Bell Laboratories, our strength and effectiveness are tightly linked to our technology base, which stands second to none among government R&D facilities in terms of scope and depth. We take great pride in our record of accomplishment in the weapons and energy R&D arenas. As we enter the last decade of the century, Sandia's research, development, and systems integration capabilities are positioned to continue a 40-year tradition of service to the nation.

The world is changing, and we must all adapt to a new environment and new needs. Sandia has always viewed the nation's national security interests as broader than just the military dimension. We recognize that national security rests on several pillars: military security, economic security, energy security, and, as is becoming increasingly apparent, the ability to protect the environment.

Interestingly enough, technology is the common requirement for success in each of these areas. We can not be militarily secure without preeminence in the technologies that comprise our weapon systems and defenses. Our economic competitiveness in international markets is dependent upon the technological ingenuity of our manufacturers and producers. Improved energy extraction, conversion, and conservation are needed if we are to reduce our dependence on foreign sources of energy. If we hope to ameliorate the alarmingly rapid convergence of environmental and climatological deterioration, we must develop entirely new technologies—technologies for minimizing the destructive by-products associated with energy utilization, for minimizing and managing hazardous wastes, and for substituting innocuous materials for hazardous substances used in manufacturing and other industrial applications.

Unfortunately, our past has been driven by crisis upon crisis. I like to think of this as our "forays with the four E's." In the 1960's, we were concerned with the Environment—mainly air quality. In the 70's it was Energy—twice becoming a crisis. In the 80's, our concern was the Economy—with large federal budget and trade deficits. Now we enter the 1990's and are faced with interrelated problems in Everything above. The problems of the 90's will only be adequately addressed by understanding the dependencies among energy, environment, and the economy. A technical advance in any one of these areas is likely to impact the other two, and, indeed, must impact the other two favorably to be worthy of pursuit. I will shortly describe some examples of technologies developed at Sandia that have positive impacts in all three areas. First, I will give a brief overview of Sandia's energy R&D programs for the Department of Energy.

Sandia's energy programs for DOE are funded at $103 million in fiscal year 1990. In addition, we are performing $30 million in energy work for other federal agencies, including $12 million for the Nuclear Regulatory Commission. The secretarial officer with the largest sponsorship of energy programs at Sandia is the Assistant Secretary for Conservation and Renewable Energy, who constitutes about one-third of our total energy programs effort. Current activities include the solar electric technologies (photovoltaics and solar thermal), wind energy, geothermal energy, high temperature superconductor technology for electric power systems, advanced materials and catalysts for energy conversion and conservation, and industrial waste management. An important objective of these programs is to establish technology bases that will support private sector efforts and to work actively with industry and users to accelerate development and acceptance of these emerging technologies.

Almost 30% of our energy effort is performed for the Office of Civilian Radioactive Waste Management and addresses the transportation and geological disposal problems of spent nuclear power reactor fuel and high-level radioactive waste. The dominant effort for this office is the Yucca Mountain project, an investigation to determine the feasibility of siting a commercial nuclear waste repository at Yucca Mountain adjacent to the Nevada Test Site. Sandia's participation in this project primarily involves studies of geological characteristics and water migration phenomena. In addition, we conduct approximately $40 million of defense-related remediation and waste management activity for DOE's Office of Environmental Restoration and Waste Management.

About 25% of Sandia's energy R&D programs is conducted for the Office of Energy Research, primarily in the Basic Energy Sciences and Magnetic Fusion programs. Basic Energy Sciences projects include an innovative program in scientifically tailored materials and a national responsibility in the combustion sciences. Sandia's Combustion Research Facility is being enlarged with construction of Phase II currently underway. In addition, our magnetic fusion energy projects are part of a long-term, nationally coordinated program with the potential for great payoff. And our earth and environmental sciences program provides a geoscience base for energy, environment, and defense needs.

Other important R&D work is performed for the Assistant Secretaries of Fossil and Nuclear Energy. The primary objective of Sandia's fossil energy program is to provide technology that expands the base of domestic energy reserves and improves the nation's ability to use our oil, gas, coal, and oil shale resources efficiently. Current efforts for the Assistant Secretary for Nuclear Energy focus principally on advanced space nuclear power applications and terrestrial reactor development—the latter emphasizing improved nuclear power plant safety, reliability, and economics.

As you know, the Department of Energy is developing an integrated National Energy Strategy that will form the basis for its energy R&D programs in the 1990's. Sandia is well prepared to help implement the National Energy Strategy, as a result of the breadth of our energy programs, our tradition of working closely with industry, and our track record of delivering useful R&D results since the middle 1970's. DOE's National Energy Strategy is organized around four themes identified by the American public during the public hearing phase of the strategy development. They are: (1) increasing energy efficiency; (2) securing future energy supplies; (3) respecting the environment; and (4) fortifying foundations. Sandia's programs are in concert with these elements of a National Energy Strategy, and I will provide several examples of R&D payoff relating to them.

Sandia is working closely with industry to increase the energy efficiency of internal combustion engines and industrial and residential furnaces. This activity is taking place as part of the Office of Industrial Technology's Combustion Technology program sponsored by the Assistant Secretary for Conservation and Renewable Energy. We are using a concept we call "Cooperative Working Groups" to optimize collaboration among the industrial, university, and national laboratory participants. Corporately funded industry partners in these working groups include General Motors, Ford Motor Company, Chrysler, Cummins Engine Company, Exxon, Navistar, Unocal, GRI, AGA, and Lennox Industries.

For example, scientists at Sandia's Combustion Research Facility, working with researchers from Lennox Industries, have together produced an advanced pulse combustor design for use in residential and industrial furnaces. Pulse combustion leads to improved energy efficiency over conventional designs. Another collaborative effort involving Sandia, the Gas Research Institute, and John Deere Technologies International has made advances with a rotary engine concept with exceptional power density. This engine concept may be suitable for large vehicles and stationary power plants. In collaboration with Cummins Engine Company, we have undertaken an aggressive program to investigate the processes which control particulate formation in heavy-duty diesel engines, and in the process, we have helped resolve a serious engine wear problem. In each of these three examples, a U.S. industrial entity has acquired a technology advantage that may be an important factor in its competitive posture in the international marketplace.

Sandia has been a major contributor in the arena of energy supply R&D. Here as well, it has been our practice to work with industry in overcoming the technological barriers to implementing new concepts. In the late 1970's Sandia engineers developed a concept of using synthetic polycrystalline diamond discs, manufactured by General Electric, in a new type of drill bit designed for geothermal, oil, and gas drilling. We worked closely with engineers from GE to develop a technique for reliably bonding the diamond discs to metal studs. We used our computer codes (derived from the weapons program) to properly position the diamond cutters on a drill bit face to ensure proper cooling, balanced cutter wear, and optimum performance. This technology was then demonstrated to the drill bit industry through a concerted technology transfer effort, and the greatly improved performance of the bits was validated through cooperative tests with the drilling industry. Today, these bits have demonstrated an improvement in drilling productivity of at least 25% in many formations. The value of this improvement in the context of total drilling activity around the world translates into a dollar impact in the billions.

Another example of a very high impact contribution to the problem of energy supply is the development by Sandia of a technique for improving the placement of oil and gas wells to help drain hard-to-tap reservoirs. This technique, called anelastic strain recovery, measures stresses in rock formations, allowing fractures from boreholes to be accurately predicted and adjacent wells to be properly positioned. Improper placement of just a single well can cause millions of dollars worth of oil or gas to be left underground. The total impact of the world-wide use of this technique in additional recoverable energy is surely in the billions of dollars.

Nuclear power is an essential component of this nation's energy supply mix, and its environmental advantages are becoming appreciated in light of world-wide concern over the emission of greenhouse gases from fossil fuel power plants. The U.S. has over $200 billion invested in nuclear power facilities that generate 20% of its electricity. Nuclear power plants are licensed for 40 years, but studies indicate that plant life could be extended by an additional 20 or 30 years. If even an average of ten years additional operation could be gained, $170 billion dollars would be saved. Sandia has devised a step-by-step methodology for evaluating plant equipment—focusing on systems, structures, and components that are subject to age-related degradation—that may pave the way for safe, extended operation of nuclear power plants. The methodology is endorsed by the nuclear power industry as its technical approach to license renewal, and has been submitted to the Nuclear Regulatory Commission for consideration in formulating license renewal regulations.

Over the years, Sandia, working with industry, has been improving the performance efficiency and cost-effectiveness of solar thermal and photovoltaic systems. The industry is now at the point where commercial solar thermal power generation may be economically viable. Luz International has constructed a modularized solar energy generating network using solar thermal designs developed by Sandia and collaborating companies. Luz is profitably selling electric power to supplement peak afternoon demand in southern California. The company has been successful in reducing its generating costs per kilowatt hour by two-thirds since its first module was brought on-line in 1985. Total generating capacity is approaching 350 megawatts, which is a little less than half the size of an average fossil fueled power generating station.

On the photovoltaic side, Sandia has developed highly efficient power modules using crystalline cells. Photovoltaic systems are ideal for small power, remote applications, and are widely installed in developing nations under aid programs sponsored by the World Health Organization, the World Bank, and the U.S. Agency for International Development. Sandia's Photovoltaic Design Assistance Center has helped U.S. manufacturers compete in this growing international market.

Much of Sandia's energy work has large potential impact in the area of environmental quality. We recently demonstrated a solar process for purifying polluted water. Building on laboratory experiments that had proved that light, together with a catalyst, could destroy common organic pollutants, we used our solar engineering experience to construct a field model of the process. Focused ultraviolet rays activate a nontoxic catalyst which facilitates the oxidation of complex organic compounds in the water. The end products are carbon dioxide, simple acids, and clean water. Clearly, the potential impact on the water pollution problem is enormous, and the cost of the process is modest. Sandia is collaborating with the Solar Energy Research Institute in Colorado and interested industrial groups to spur rapid transfer of the technology to the commercial sector.

Mixed organic, inorganic, and radiological wastes are another problem, however. There is currently no environmentally safe process for removing organics from mixed wastes, which is essential in order to prevent leeching from radiological wastes stored as glass or grout. One technology that holds promise, however, is supercritical water oxidation. At least three companies in the United States are trying to commercialize supercritical reactors to destroy hazardous wastes, but, due to resource limitations, they are unable to address the fundamental issues involved in the process. Scientists at Sandia's Combustion Research Facility and Los Alamos National Laboratory are collaborating with these industries to advance their development of the technology. The promise this technology holds is for an economical, efficient, and environmentally safe method to treat or destroy a significant share of the aqueous wastes that threaten to choke our nation. The process will be an important tool in the clean-up of the nuclear weapons complex, and will be directly applicable to the waste treatment problems of the electronics industry and other manufacturers.

Sandia has conducted significant R&D in the management, packaging, transportation, and storage of radioactive wastes, and with our close ties to the production agencies of the nuclear weapons program, we are introducing innovations in waste minimization for manufacturing. We are developing new processes to minimize the environmental impacts of manufacturing through substitution of less hazardous process chemicals and improved techniques for recovery and recycling. Water-based solvents, less hazardous curatives, dry machining, new cutting fluids, and fluxless soldering are examples of such improvements. These improvements will also result in lower costs for disposal and worker protection. Innovations such as these could be applied by U.S. industry to their own manufacturing waste problems and in turn be marketed by U.S. industry world-wide.

Another environmental threat of concern internationally is the phenomenon of global warming. The U.S. can be a leader in the characterization and measurement of the problem. And, if the magnitude of the situation warrants, we can also be a leader in the development of cost-effective, sensible applications for ameliorating it.

Sandia, in collaboration with other national laboratories, has begun a promising new program in global change research. The thrust of this program is to combine our experience in instrumentation and sensors, systems engineering, and supercomputing to perform remote sensing and data analysis of the atmosphere. Initial efforts are directed at improving the general circulation models now used to guide policy. We are also in the initial phases of exploring possible collaboration with NASA and industry to help develop space-based or aircraft-borne instrumentation for climate studies.

Besides characterization and study of the problem, we are at the same time exploring solutions. For example, we are developing coal conversion techniques using catalysts that significantly reduce the undesirable by-products of coal combustion. Specifically, we have designed a new class of catalysts useful in converting coals to liquid fuels and in refining crude oils that has been demonstrated by industry to be superior to the commercial catalysts currently available. Continued improvement in catalyst design will permit large-scale commercial processing of cleaner-burning fossil fuels with greater hydrogen content and reduced nitrogen and sulfur. The potential market value of such catalysts when transferred to U.S. industry will be in the hundreds of millions of dollars per year. We are also forming alliances with the industry to address key issues in coal utilization. And we are exploring a partnership role with a new Auto/Oil Consortium, established by the transportation industry to provide workable, long-term solutions to clean air problems.

The fourth theme raised by the public during the hearings phase of the National Energy Strategy is "fortifying foundations." These foundations are the infrastructure, understanding, and expertise that comprise our science and engineering technology base. According to figures kept by the National Science Foundation, industry and the federal government have shared the funding support of this nation's R&D technology base in approximately equal measure since the early 1950s. I would hope that this partnership would continue, although the portion of federal participation has been in decline since 1979.

Education is part of our foundations too, and Sandia is responding vigorously to Secretary Watkins' call for stronger support of science education by DOE laboratories. Locally, we have several new initiatives in progress, including an innovative program of furnishing science advisors to schools, conducting teacher training workshops, developing curriculum support materials, and providing opportunities for hands-on science experience for appropriate groups. At the state level we are moving forward to establish a science curriculum support center, develop a "moving classroom" using instructional television and computing, and provide teacher certification support and continuing education offerings. At the national level, we see a need for offering curriculum support (affordable, packaged laboratory experiments and materials, for example), forming partnerships with foundations involved in science education, and using contract leverage with university grants to involve principal investigators in science education. We also see a need for correcting the unflattering stereotypes of scientists and engineers projected by the entertainment industry.

Above all, the foundation of Sandia's success in making important contributions in both defense and energy R&D is its superb technology base supported by Defense Programs and Basic Energy Sciences. Without this consistent level of base support for its facilities, equipment, and technical expertise, the Laboratories would simply not have been able to demonstrate the innovative, responsive work they have become known for.

This technology base support is not an expense, it is an investment—an investment with high leverage impact for American innovation and competitiveness. It is innovation, and not capital alone, that drives industrial competitiveness, and the national laboratories are a catalyst for innovation with industry. Just last week, I participated with Secretary Watkins in a signing ceremony in the Dirksen Senate Office Building establishing a DOE/industry consortium of U.S. specialty metals processing companies to collaborate in generic, pre-competitive R&D in manufacturing process control. Our nation's producers of specialty metals for high performance applications such as aerospace have been facing concerted competition from Pacific Rim countries who have developed a strong capability in this technology and are projecting an aggressive presence in what is a $6 billion U.S. market. The participating firms will work together to advance the state of their art so they can individually become more competitive in the international market. Sandia is the catalyst in this interaction, providing a base of expertise in materials science and fabrication engineering that it has established over many years in the weapons program.

Sandia's approach to technology transfer emphasizes rapid commercialization through internal technology maturation and flexible, project-specific collaboration with industry. We believe that shorter product development cycles are crucial to improved competitiveness by U.S. industry.

Sandia accelerates the development of technologies with high commercial potential under its Technology Maturation Program. The purpose of this program is to advance the commercial applicability of promising technologies to where they may attract commercial interest. Several projects in the Technology Maturation Program are especially exciting. These include: simplified computer programming of numerically controlled machines, non-invasive techniques for measuring blood glucose, solar detoxification of water polluted with organic compounds, advanced steel processing techniques, automated edge finishing, image recognition techniques for medical diagnosis, advanced electro-deposition processes, and others.

The national laboratories have a wealth of ideas and capabilities that can be applied to pressing national and world problems. More importantly, we have demonstrated that collaboration and partnership with industry and pure research (such as universities) is an effective team approach to advancing America's superb research capabilities to practice.

We have a tradition in this country of rugged individualism. But in today's competitive environment, where foreign rivals collaborate and often benefit from protection or sponsorship from their governments, the rugged individualists are having a very tough time. Indeed, the vast majority of our start-up enterprises fail, and established companies are finding the competition to be more formidable than ever. But we don't need an American version of MITI or some new agency; the necessary institutions are already in place. What we do need is a new culture of teamwork and cooperation that unites industry, universities, government, and the national laboratories as partners on the same team.

The challenges of the 90's are multidisciplinary. In my view, environment, energy, and economic competitiveness are tightly linked as a single field of endeavor where the national laboratories will make outstanding contributions in the future.

Senator BINGAMAN. Thank you very much, Dr. Narath.
Dr. Nuckolls.

STATEMENT OF DR. JOHN H. NUCKOLLS, DIRECTOR, LAWRENCE LIVERMORE NATIONAL LABORATORY

Dr. NUCKOLLS. Thank you, Senator Bingaman and Senator Domenici. I am pleased to appear here today.

The Livermore Laboratory began to diversify as far back as the 1970's from our original nuclear weapons mission. Today we have major programs in several non-defense areas, including, principally, laser isotope separation and fusion, as well as biomedicine, the environment, and fossil energy.

We are multi-disciplinary and vertically integrated, as has been mentioned before, which translates that we can span the role from basic research to what the private sector does. As I say in my statement, my view of how the national laboratories play in this is to form a partnership with the universities on the one hand, which are principally our strength in basic research, and with the private sector on the other, which does manufacturing.

Now, clearly, the interfaces are somewhat fuzzy. We work back and forth across all of them. But I think by being able to forge the gap between the universities and the private sectors, the laboratories can give the Nation a strong competitive advantage. In fact, I call this a synergistic superpartnership.

I think the labs multi-disciplinary, large-scale applied science and engineering capabilities clearly distinguish them from the universities. At the same time, the national laboratories differ from the private sector R&D organizations in our emphasis on highly leveraged, long-range, high-risk research. And also in our focus on public service and national needs.

I believe, in this partnership, the national labs would make three critically important contributions. First, bridging the gap between the university research and the private sector. This is important, otherwise U.S. research will continue to preferentially feed our competitors.

I think we can bring a long-range focus to this gap also. And without that long-range focus, I think the United State's present increasing affliction with "now-nowism," to use Darman's words, will undermine our economic strength.

But most important, I think the national laboratories can make an important contribution in the creation of revolutionary new technologies, which I believe are essential to leapfrog our competitors, and to meet tomorrow's challenges at an affordable price.

It is my view that there is no zero sum bridge to an acceptable future. And by that I mean I do not believe the problems of tomorrow will be solved without creating and implementing revolutionary new technologies. And I think the national labs can play a critical role in that process.

Now before I say more about that, I would like to mention a few words about peace. There has been much talk about peace dividends. In my view, the first and most important peace dividend is the opportunity to continue sustaining peace itself.

It has been mentioned that when the weapons laboratories developed revolutionary nuclear technologies applied to warfare, all nations had to rethink the institution of war. I think an important goal of the labs in the next 40 years is to make the next 40 years like the last 40 years, an unprecedented period without major war.

Several speakers have mentioned the build-down in nuclear forces of the USSR, if an when that occurs. In addition, the nuclear forces of the 21st century certainly have to be made sufficiently safe, secure and survivable, and we must sustain WRD&T funding in order to achieve this transformation.

At the same time, we have not mentioned that we cannot allow the world's great population centers to be threatened by weapons of mass destruction, nuclear, chemical, or biological, launched either by renegade nations or by organized terrorist groups. We must develop appropriate defense technologies for this threat.

It is also important that we address ahead of time the potential causes of war in the 21st century. And that is what a lot of this that we are talking about does as a spinoff. And by that I foresee as those causes exhaustion of the world's oil and gas resources, environmental damage, global climate change, a century-long economic gap between the rich nations and the poor nations, and of course, those ancient enemies, ignorance, tyranny, and disease.

I do not think we can take peace for granted. We are moving into a more turbulent, less stable, multipolar world, which we do not understand. A world which may be more dangerous than the bipolar world of the last century.

Now let me turn back to civilian applications, which of course play on these causes of war, also, but which are essential to build the Nation's economic strength, which underlies all of our strength.

In the issue of the depletion of oil and gas, the world cannot forever go on burning coal, not only because we will run out of it, but also because long before we exhaust the world's coal supplies, we will change the global climate. We have had a glimpse of what that is going to bring for the world in North Africa in the past decade, where millions of people died of starvation. However, there is an important difference. In the 21st century many of the losing nations will be armed with weapons of mass destruction. And that is why I list this as a principal possible cause of war in the next century.

Nuclear fission may be able to solve this problem, providing they can avoid accidents, solve their waste problem, and reduce the capital costs to levels affordable by the capital-poor developing nations. And this is the essential difficulty that the renewable energy competitors must satisfy.

I think the national labs can have an important role in this. We are already the leaders in the development of fusion energy. Fusion, as you know, has an important advantage over fission, a thousand-fold less nuclear waste. Recent progress has brought fusion to the threshold of scientific feasibility. The major challenge is to develop a practical power plant, which is economically attractive.

As you may know, Livermore is a leader in pushing inertial fusion as well as magnetic fusion. In fact, we have the largest inertial confinement fusion program in the world coming out of our weapons program. This is an excellent example of dual-use technology which is applied both to the defense sector and to the civil sector.

Recently, we have proposed pushing to the next step by upgrading our NOVA laser, which is the largest in the world, and we understand that this move is being strongly supported by Secretary Watkins' Fusion Policy Advisory Committee. The Fusion Policy Advisory Committee also strongly supports MFE, which is the older and more advanced approach to practical fusion energy.

The Livermore Laboratory is strongly interested in the development of these fusion technologies, and believes that the Congress should increase its support for these endeavors.

Now let me turn to another example that Livermore has developed, which is ready to go out to the private sector in this century, and that is our AVLIS laser isotope separation. I think this example tells something about what the national laboratories can contribute broadly to the private sector. As you know, in this technology we have developed ultra-stable high-power lasers, and we are using them in this approach to produce enriched uranium for the civilian nuclear fission power plants.

We are world leaders in this technology, and it has a large economic advantage over competing centrifuge and gaseous diffusion technologies. We are moving rapidly to select an industrial contractor in this decade, and to move this technology out.

AVLIS is expected to have a multi-billion-dollar impact on the economy during this decade, and up to $10 billion per year in the next century if nuclear fission energy expands. The AVLIS program is more than a major technological and economic success. It demonstrates that the vertically integrated national laboratories can make a revolutionary technological advance which is economically attractive, and which has a multi-billion-dollar impact on the economy.

Now that goes back to a question that has been raised several times this morning and which I have been puzzling over for quite some time; that is, how does the Congress determine how much money to put into the national laboratories. I think the answer is as follows.

The national laboratories have always had a very high economic leverage on the U.S. economy, whether it is their work in nuclear weapons which limited the size of the U.S. defense budget and enabled the Russians to go bankrupt first or whether it is in the private sector area on a project like AVLIS which, alone, will bring as much return to the U.S. economy as a great part of the funding of all the DOE national laboratories.

I think on an even nearer term scale, our contributions to the private sector through technology transfer can bring the same kind of economic leverage to the U.S. economy.

If we turn to the environment, we see the same pattern. The cleanup bill for the DOE sites is estimated to run on the several-hundred-billion-dollar year level so far. I think if we include the cleanup bill for DOD as well as for the private sector that we are looking at a several-trillion-dollar bill. If we consider the market for the rest of the world, we are certainly looking at a multi-trillion-dollar endeavor.

For the United States, unless we can find a smart way to do this cleanup, it is going to be much worse for the U.S. economy than the savings and loan. I think the national laboratories can provide that smart technology, probably a factor of at least 2 and I would hope a factor of 10 or more, reducing that multi-trillion-dollar bill. So I think there is no question that the moneys that are spent in the national laboratories on this endeavor will have a payoff back to the Nation many times larger than what the Congress invests.

I would encourage the Congress to look at the investments in the national laboratories in this light. Clearly, project by project you cannot do this. I think as the years go by and you look at the long-range roles of the laboratories, you should assure yourselves that indeed what you are putting into the laboratories is return to the Nation with a very large multiplier—in fact, I would hope a factor of 10 to 100—in which case you will have no question about whether you are putting too much money in but, rather, you will be asking yourself the question whether it would be better to put more money in.

If we are only producing a 10 percent return on the money you invest, then I think inevitably the question is going to be raised if this is the right place to invest and is this the right amount.

I think biotechnology is another area where the laboratories are off to a strong beginning that can have a high payoff for the Nation. The Nation's total spending on health care is now running at $700 billion per year and rising. I think the human genome project is the beginning of a revolution which will come to fruition in the next century and will have a major impact on health and productivity and, I hope, a slowing down of the growth of the Nation's spending on medical care as we learn to cure diseases by genetic means.

I have touched on several areas of economic competitiveness: First, AVLIS, which can impact on market on the $1 billion to $10 billion per year level.

I would like to touch again on fusion which I mentioned earlier. If the United States can develop an economically attractive power plant, then it can have an enormous market in the 21st century. If you calculate the market for power plants in the 21st century given the developing world and assuming they come up to some tiny fraction of the energy capabilities that the developed world has, it works out to something like $100 trillion.

If you say the world does not have enough capital to make that kind of investment, which indeed turns out to be true, you end up with a lower limit of $10 trillion. So we are looking at a market which is going to run several hundred billion dollars per year in the next century. There is an enormous payoff for the United States to be the country that develops the power plant that is the equivalent of what Boeing does for the aerospace industry or what IBM does for the computer industry.

This is an example where the national laboratories can have an even larger leverage by a factor of 10 to 100 than we have done for AVLIS already. I think that Congress should move out expeditiously on that and not give all the technology away.

Now as far as technology transfer is concerned, we at the laboratory have some 50 industrial partnerships. We also have some 50 companies that have been formed by our ex-lab employees based on technologies developed at the laboratories. These companies have created hundreds of millions of dollars per year of sales domestically and internationally. They have had major market impacts in areas such as computer-aided engineering and design, instrumentation, lasers and pulse power. The movement of people from the laboratory to industry is one of the very best forms of technology transfer, as has been mentioned earlier.

I would like to call your attention to one specific example of technology that has come out of the laboratory which has not worked right but which has had a very positive impact on the industry of the entire world. That happens to be the DYNA-3D computer code which was developed to calculate bombs smashed into the ground but can just as well be used for all sorts of industrial processes.

This engineering code was originally written in 1976 and went out of the laboratory before software could be copyrighted or patented. It was not picked up by the U.S. private sector but was picked up by the Japanese. None of the private sector companies originally wanted it because they did not own the copyright rights to it. It is now being used by 300 private-sector organizations worldwide including a large sector of American industry.

The codes based on DYNA-3D are used in many industries, including automobile crash simulation by many of the world's automobile manufacturers, aluminum can manufacturing, design of jet engine fan blades, the safety of shipping containers for hazardous materials and, most recently, it is being applied to study earthquake safety. We have been able to reproduce the failure of the Cypress overpass in Oakland.

I think in the future we have to be careful not to have this kind of an example repeated. It shows not only the high leverage that the technologies developed in the laboratories can have, but it also reminds us of something mentioned here earlier. The laboratories have got to be enabled to play a key role in seeing that this technology goes to the private sector of the United States first rather than helping our competitors.

As Secretary Watkins has mentioned, this laboratory is involved in several large educational initiatives. We have been a leader in that. More than 1,000 laboratory employees have volunteered to help the educational system. Our program goes back 10 to 20 years. We have more than 64 science education programs involving students from kindergarten to the university. I might say that our programs were not a result of management foresight but were a result of grassroots efforts on the part of our employees who were terribly interested in the educational system, having had children, and also interested in that as a national problem. That is something in which we are terribly interested, and we certainly appreciate your help and support in that.

Finally, let me say a few words about our institutional research and development program, which has been the subject of some comment in the last few months.

We are very excited about this program, and it has had high payoff at the laboratory. Let me mention a few examples. Some years ago we formed a project to investigate the development of super plastic steel with a goal of forming complex steel parts more economically by avoiding most of the machining. This has led to a recent joint initiative between DOE and the private sector that promises substantial economic benefits for the U.S. industry and also reduces the waste generated with traditional manufacturing.

We are also now funding a parallel processing software computer initiative that should make possible continued American leadership in application of supercomputers. This will continue the national security labs 40-year record of fostering development of the supercomputer industry, a public service which has provided an important competitive advantage for the United States.

We have other projects which I do not have time to mention, but including laser-assisted processing of semiconductor materials, neural networks, and we are also pushing the development of x-ray lithography, which is part of an intense international competition for future leadership in the semiconductor and computer industries.

With that, let me close.

[The prepared statement of Dr. Nuckolls follows:]

STATEMENT OF JOHN H. NUCKOLLS, DIRECTOR
LAWRENCE LIVERMORE NATIONAL LABORATORY
before the
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
of the
SENATE ENERGY and NATURAL RESOURCES COMMITTEE

July 26, 1990

Mr. Chairman and Subcommittee Members, I am pleased to appear here today to discuss the current programs and the potential for new or enhanced future programs for the Lawrence Livermore National Laboratory.

Throughout the Lawrence Livermore Laboratory's 38-year history, national security has been our paramount focus. From time to time the Federal government has broadened our mission to address important new national needs. In the 1970's we began a major expansion and diversification. Today, in addition to defense, our mission includes energy, biomedicine, the environment, science and math education, and technology transfer.

We have major programs in three areas: nuclear weapons, laser isotope separation, and fusion energy, as well as substantial programs in biomedicine, environmental restoration, and fossil energy. Livermore and our sister nuclear design laboratory, Los Alamos, are premier large-scale applied science laboratories -- each with some 8000 uniquely skilled University of California employees and multibillion dollar plant and research facilities. We are preeminent in large-scale modeling with the most advanced supercomputers, in the approach developed by E.O Lawrence for the organization and management of large multidisciplinary scientific teams, and we are vertically integrated -- we span the transition from basic research through development and engineering to the manufacturing, development, maintenance, and retirement of our products.

For the future, the mission of the labs must broadly encompass national security as outlined by Senator Gore, "those matters that can directly and imminently menace the interest of the U.S. and the safety of the American people at the fundamental level of survival."

UNIVERSITIES, NATIONAL LABS, PRIVATE SECTOR

The National security labs are unique institutions - in the nation and in the world. They span the wide gulf between the universities and the private sector. By forging a synergistic superpartnership among the universities, the national labs, and the private sector, the U.S. can develop a powerful force for change and a strong competitive advantage.

The labs' multidisciplinary, large-scale applied science/engineering capabilities distinguish them from universities. Both the universities and the laboratories have multiple disciplines, but the labs are unique in the use of large multidisciplinary teams to solve large-scale problems that require the skills of many disciplines, the development and use of large research facilities, and the development of a product rather than the publication of a paper in a professional journal.

Given the growing complexity of the problems which must be solved, it is often at the interface between two or more scientific fields where exciting new discoveries are made. For example, research at Livermore and at the Lawrence Berkeley Laboratory has combined the talents of biologists and physicists to use a scanning tunneling microscope to photograph individual DNA molecules for the first time.

The National Laboratories differ from private sector R&D organizations in our emphasis on highly leveraged, long-range, high risk multidisciplinary research -- and in our focus on public service and national needs. In the past decade, corporate America has become increasingly more focussed on the bottom line. The preeminent private sector labs -- AT&T Bell Telephone and IBM Yorktown -- are becoming more short-term and product oriented. Congress should see that the national labs fill the resulting vacuum, otherwise the nation will lose one of its major competitive advantages during the past half century.

In this synergistic superpartnership, the national labs would make three critically important contributions: bridging the gap between University research and the private sector -- without which U.S. research will continue to feed our competitors; a long range focus -- without which U.S. affliction with "now-nowism" will undermine our economic strength; and the creation of revolutionary new technologies which are essential to leapfrog our competitors and to meet tomorrow's great challenges at an affordable price. There is no zero sum bridge to an acceptable future. The problems of tomorrow will not be solved without new institutions capable of creating and implementing revolutionary new technologies.

To meet tomorrow's challenges, the national security labs must substantially increase their capabilities, for these challenges are far more difficult than ever before. At LLNL we are focussing on several areas where technological revolutions are occurring -- supercomputers, experimental technologies, and new state of the art research facilities. We are also fostering increased openness, building partnerships with the private sector and the universities, and enhancing our coupling to absorb the worldwide advances in science and technology.

PEACE

The first and most important peace dividend is sustaining peace itself. Wars have been fought for thousands of years -- culminating in the two great world wars of this century. As Senator Gore recently noted, when the weapons laboratories developed revolutionary nuclear technology applicable to warfare, all nations had to rethink the institution of war.

An important goal of the national security labs must be to make the next 40 years -- like the past 40 years an unprecedented period without major war -- a period of continuing survival and success of liberty.

We must reduce the size of our nuclear forces and those of the USSR. The nuclear forces of the 21st century must be made absolutely safe, secure, and survivable. WRD&T funding must be sustained while we achieve this transformation. Priorities for WRD&T have changed, but responsibilities have not diminished.

Openness must be greatly enhanced. Transparency can be fostered by proliferating small satellites and making the observational data available to all nations.

We cannot allow the world's great population centers to be threatened by weapons of mass destruction -- nuclear, chemical, or biological -- launched by renegade nations or by organized terrorist groups. We must develop appropriate defense technologies.

Most important, we must address the potential causes of war in the 21st century -- exhaustion of the world's oil and gas resources, environmental damage, global climate change, a century long economic gap between the rich nations and the poor nations, ignorance, tyranny, and disease. We must avoid hot wars and cold wars.

Peace cannot be taken for granted. We are moving into a more turbulent, less stable, multipolar world -- a world which may well be more dangerous than the bipolar world of the past half century.

Currently, about 70% of our Laboratory personnel are devoted to defense. As the focus shifts from defense to broad national security challenges, we will access Senator Nunn's peace dividend -- more of the Laboratory's R&D talent will be deployed to meet challenges in the energy, environment, biotechnology, and economic areas.

ENERGY

In this next century, the world's supply of oil and gas will be exhausted. Substitution of coal will lead to potentially disastrous global climate changes.

In the past decade in North Africa we have seen the fate of the future losers in this deadly game of climate roulette. Millions of people have died of starvation. However, there is an important difference: in the 21st century many of the losing nations will be armed with weapons of mass destruction. Nuclear energy may supplant coal and avoid this potential disaster providing that nuclear accidents can be avoided, the waste problem can be solved, and the capital cost can be reduced to levels affordable by the capital-poor developing nations.

The national labs will have an important role in developing new energy sources that in the words of Senator Nunn "meet the security and industrial needs of the next century, at costs that are consistent with a robust economy, and in forms that relieve pressure on the global environment."

Fusion energy has strong advantages in the environmental and safety areas. Recent progress has brought fusion to the threshold of scientific feasibility. The major remaining challenge is to develop a practical power plant which is economically attractive.

The Lawrence Livermore Lab is a world leader in fusion energy R&D. We are researching both the magnetic confinement and inertial confinement approaches.

Our ICF Program is the largest and most advanced in the world. Its centerpiece is the NOVA laser, by far the most powerful in existence. ICF is supported by DOE Defense Programs because of the defense application of small laboratory fusion explosions. The energy application of ICF is an excellent example of transferring the results of defense research to peaceful applications. In this project, defense scientist and engineers are already working to solve the critically important civil energy problem. There has been outstanding technical progress in the past few years. We are proposing to upgrade NOVA to demonstrate the achievement of fusion ignition before the end of the decade. This NOVA upgrade has been supported by Secretary Watkins' Fusion Energy Advisory Panel. Because ICF grew out of the weapons program, the U.S. could sustain world leadership in the development of ICF and could dominate a several hundred billion dollar per year commercial power plant market in the next century.

The Congressionally chartered National Academy of Sciences Committee has recently expressed confidence in the high quality of ICF science and technology -- although this Committee was not chartered to examine the energy application.

FPAC strongly supports MFE, which is the older and more advanced approach to practical fusion energy. Lawrence Livermore Lab is leading the U.S. team in the international effort to design the world's first magnetic fusion reactor. Soviet, Japanese, European, and American fusion teams are designing this multibillion dollar International Tokamak Energy Reactor (ITER) project originally ratified in a Reagan-Gorbachev summit agreement and supported by Bush and Gorbachev at the recent summit.

While developing fusion as revolutionary energy technology for the next century, the Lawrence Livermore Laboratory has at the same time developed a revolutionary energy technology which is ready for deployment in this century: Atomic Vapor Laser Isotope Separation (AVLIS). Ultrastable high power lasers are used to produce enriched uranium for civilian nuclear fission power plants. We are world leaders in this technology which has a large economic advantage over the competing centrifuge and gaseous diffusion technologies. The DOE is moving rapidly to select an industrial contractor to take the lead in deploying this technology. LLNL is strongly dedicated to successfully developing this technology and is supporting its deployment at the earliest possible time. AVLIS is expected to have a multibillion dollar impact on the economy during this decade and up to 10 billion dollars per year if nuclear fission energy expands in the next century. In this scenario the U.S.

would build a series of AVLIS plants each more advanced -- so that the U.S. stays ahead of foreign competitors. AVLIS can ensure a dominate role for the U.S. in the nuclear fuel enrichment market place.

The AVLIS program is more than a major technological and economic success. It demonstrates that the national security labs can make a revolutionary technological advance which is economically attractive, and which has a multibillion dollar impact on the economy.

ENVIRONMENT

Nuclear energy, fission and fusion, can potentially limit global climate change. In the near term it is also essential to develop our capabilities to understand and predict these changes. The Laboratory is a leading DOE center for the study of global greenhouse warming using large supercomputer programs. Last year we initiated a new program for climate model diagnosis and intercomparison. So far even the best climate models cannot reliably include the effect of clouds and the results are very sensitive to the modeling of clouds. Coupling between the atmosphere and the ocean is also not well understood. We are collaborating with Los Alamos and Scripps Institution of Oceanography in a study of the earth's ocean and atmosphere. We are studying the application of low orbit minisatellites to obtain the necessary observational data. Global climate change is also driven by trace gases which are much less abundant than CO_2 but are much more effective as greenhouse gases. We are a leader in upper atmosphere chemistry research to understand the effect of trace gases on global warming, and on the depletion of ozone.

In the area of environmental restoration, the lab is focussing on cleanup of the DOE sites. At the same time we are developing new approaches to minimizing the generation of waste. Our goal is "smart" cleanup - a major reduction in the projected costs. Cleaning up the nation's environment -- in the defense and private sector -- will cost trillion of dollars unless we develop more efficient and effective approaches. The labs large-scale multi-discipline, vertically integrated approaches are essential to these tasks. There is no doubt Senator Nunn was correct when he said environmental technology is likely to be the growth industry of the next 20 years.

BIOTECHNOLOGY

One of the most exciting projects in current biomedical research is the effort to characterize the human genome. Recently the Lab was designated a national center for genome research after Los Alamos and Lawrence Berkeley Lab. This project is part of the beginning of a major revolution which will come to fruition in the next century. We may expect substantial improvements in the quality of life, in health and productivity, and perhaps a slowing down of the growth of the nation's spending on medical care, now 700 billion dollars a year. I have already mentioned our collaboration with Lawrence Berkeley Lab to image DNA. We also made important progress in developing our laser excited florescent tagging technique which can quickly and easily detect certain classes of genetic abnormality. We believe this will become an important tool for the prenatal diagnosis of genetic defects.

We are also applying a novel method for measuring mutations in red blood cells via monoclonal antibodies. We have measured genetic damage in survivors of Hiroshima, Nagasaki, and Chernobyl. We have also applied this technique to persons not subjected to excessive nuclear radiation who have inborn deficiencies in their DNA repair mechanisms. These individuals show clear elevations in the number of red blood cell mutations and an increased risk of cancer.

In addition to the application of our expertise in lasers to biotechnology, we have also applied our expertise in accelerators. We are using our Accelerator Mass Spectrometer to measure genetic damage with thousand-fold greater sensitivity than previously possible. This technology promises safer drugs and a quantitative understanding of the cancer causing potential of industrial chemicals and natural products. It will also assist us in setting safer radiation standards.

ECONOMIC COMPETITIVENESS

A strong, competitive economy is essential to national security. The nuclear weapons labs have had high economic leverage. Without nuclear weapons the U.S. would have been forced to match Soviet conventional forces. Our defense expenditures would have been much larger and our economic competitiveness would have eroded long ago. The National labs can make multibillion-dollar per-year contributions to our economy through development of revolutionary new technologies such as AVLIS, and environmental restoration. In the longer range the labs can make multi-hundred billion-dollar per-year contributions by developing revolutionary new technologies such as fusion energy and the biotechnologies. They are also making near term contributions through technology transfer.

Last year, Congress made technology transfer a mission of the National laboratories. We are working with industry to promote technology transfer by providing a wide variety of technologies from which to choose out of the incredibly rich technology base that resides in the DOE weapons laboratories, and by developing new relationships with industry.

I'd like to share with you a few examples out of the fifty or more partnerships with industry that we have negotiated over the past three years:

- We're working with a firm to produce a new generation of industrial machines that permit three-dimensional inspection of a product while mounted on a cutting machine.
- Under a cooperative agreement, a major U.S. biotechnology firm will fund research and development over three years to produce DNA probes for cancer detection, hereditary disease detection, and prenatal testing.
- We're licensing American companies to produce new materials called cermets; a combination of a ceramic and a metal.
- Eight oil companies are funding our effort to develop computer models which will help locate new oil deposits.

Some fifty companies have been formed by our ex-employees, based on technologies developed at the Laboratory. These companies have created hundreds of millions of dollars per year of sales domestically and internationally. They have had major market impacts in areas such as computer aided engineering and design, instrumentation lasers and pulsed power. This movement of people from the laboratory to entrepreneurial industry is one of the very best forms of technology transfer.

The computer code DYNA-3D is a good example of how work done for national security can make major contributions to American industry and our economic competitiveness. This engineering design code was originally written in 1976 to model the time dependent effects of stress and bending on materials subject to strong forces. It is now in use by more than 300 private sector organizations worldwide including a large sector of American industry. Codes based on DYNA-3D are applied in a variety of industries including automobile crash simulation by many of the world's automobile manufacturers, aluminum can manufacturing, the design of jet engine fan blades, and the safety of shipping containers for hazardous materials. Since the California earthquake last October, these codes have been applied to understand the failure of bridge and highway structures including the collapse of the Cypress Overpass in Oakland.

These examples suggest that the U.S. investment in the national security labs is sound economics -- with long-range payoffs tens to hundreds of times larger than the public funds invested.

EDUCATION

A highly educated work force is essential to the future of the nation. We spend approximately as much on education in terms of percentage of GNP as other countries, but foreign science and math students are much better educated. Just as we need "Smart" energy and, in the case of environmental cleanup, "Smart" clean-up, we need "Smart" education.

The National Science Foundation predicts that by the end of this decade there will be a shortage in the U. S. of several hundred thousand scientists and engineers. In the United States, there are only 53 scientists and technicians for every one thousand of the Population. This compares to 317 per thousand in Japan and 139 in West Germany. Relative to the competition the U.S. already has a shortage of 10 million scientists and engineers.

Secretary Watkins has made a partnership with scientists and math educators a mission of the national laboratories in order to develop programs that would stimulate interest in technology and science. A thousand Lab employees have volunteered to help the educational system. Livermore now has 64 science education programs involving students from kindergarten to the university. This is more than any other U.S. national laboratory. For example, our Science Education Center was opened nearly a decade ago. It has since become the model for similar facilities at other laboratories. The Center is used for everything from teaching small children how to write their own computer programs to training teachers.

Recently the Bay Area Science and Technology Consortium was created. This program involves Livermore, Sandia, LBL, and the Stanford Linear Accelerator Center, together with the California State Department of Education, UC Berkeley, and the Lawrence Hall of Science. The goal of this consortium is to enhance science and math instruction in the Bay Area public schools. The initial focus will be the Oakland public schools -- one of the many large, troubled school districts in the nation. The consortium will train teachers in science at the laboratories, loan equipment and computers to the schools and send its own scientists into the classrooms to teach.

I believe the Laboratory can make an important contribution to the nation through science and math education. Every person we help to have a career in science and math will return that investment to the nation many times over.

INDEPENDENT RESEARCH AND DEVELOPMENT (IR&D)

We are fostering the development of revolutionary new technologies and new programs through the IR&D process which is funded by a small tax on all Laboratory programs. By encouraging employees to suggest new research projects and apply for funds on a competitive basis, the IR&D program identifies and nurtures new directions, encourages innovation, explores new ideas, and develops new leaders.

We have seen many exciting payoffs from this five-year-old program. For example, in 1985, the LLNL IR&D program sponsored a small project to investigate the development of superplastic steel with the goal of forming complex steel parts more economically by avoiding most of the machining. This has led to a recent joint initiative between DOE and the private sector that promises substantial economic benefits to U.S. industry and at the same time greatly reduces the waste associated with traditional manufacturing methods.

The IR&D program also funded the development of a new technology using an accelerator mass spectrometer that permits the extension of radiocarbon dating procedures to clinical and biomedical research applications (as mentioned earlier).

IR&D is now supporting a parallel processing software supercomputing initiative that should make possible continued American leadership in applications of supercomputers to R&D and to U.S. industry. This will continue the national security labs' 40-year record of fostering development of the supercomputer industry -- a public service which has provided an important competitive advantage for the U.S.

Ongoing IR&D projects include laser-assisted processing of semiconductor materials, ocean circulation models, neural networks, and x-ray holography of living cells. We are also assisting in the development of x-ray lithography which is part of an intense international competition for future leadership in the semiconductor and computer industries.

CONCLUDING REMARKS

Forty years ago when the national labs were created by the Congress and Presidents, those men and women of vision may have foreseen that the labs would have an important role in achieving an unprecedented era of peace with the end of the cold war, world leadership in scientific research, and the development of nuclear power.

Forty years from today in the 21st century, future generations will look back on Congress' leadership and vision and that of the President and of Secretary Watkins in redirecting the national labs to help maintain world peace and U.S. leadership in scientific research, address the causes of war, develop future energy sources, protect the environment, enhance human health and education, and to build a strong and competitive U.S. economy.

Thank you for this opportunity to participate in your review of the national laboratories and their programs. In addition, I personally want to thank you, Senator Ford, and the Members of this Subcommittee for your support.

Senator **Bingaman**. Thank you very much, Dr. Nuckolls. I have a variety of questions I could ask. I am sure Senator Domenici does as well.

We have another panel which has come to town in expectation of testifying, and in light of that at this point I would go ahead and call them forward, because we are quickly running out of time for the hearing, but we appreciate very much the testimony. I think it has been good information for us, and I hope we can act on it.

Thank you all very much.

Would the second panel please come forward, and we will have each of them summarize their testimony.

Senator **Domenici**. Mr. Chairman, I wonder—it is just possible that I will be able to spend a little more time. I am not sure of that, but could you, if it is not too big an inconvenience, ask the last three witnesses if they would just wait a few more minutes?

Senator **Bingaman**. Why do we not ask if the witnesses who just testified could remain, and if it is possible, for us to remain after this other panel is through, we may have some questions to put to people.

Dr. Trivelpiece, why don't you go right ahead? We appreciate you coming and would ask if you could take 6 or 8 minutes to summarize your statement, that would be most useful.

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OAK RIDGE NATIONAL LABORATORY

Dr. **Trivelpiece**. I could probably do it faster than that. As you know, I have appeared before this committee on quite a few occasions during the 6 years I was Director of the Office of Energy Research. I think those 6 years give me a unique perspective in terms of not only what the Office of Energy Research laboratories can do, but also the weapons laboratories, and I did work at Livermore for a while, consulted for Sandia and have been on an advisory committee for Los Alamos.

I guess I would chide my colleagues a little bit for not mentioning the nonweapons laboratories. I would have mentioned the weapons laboratories in some detail, had I been given time to do so. I think that all the laboratories have a great deal to bring to the table in this type of a situation, that the circumstances have changed and clearly things need to be examined.

But I was interested in questions that were asked at the outset by Senator Ford, and let me use those as a basis for answering a couple of questions, and then with your permission what I would like to do is to prepare some additional remarks and have them included in the record, if the record could be kept open, because there are many things that have come up during the course of discussion I would like to have a chance to get into the record as well, if that would be agreeable.

Senator **Bingaman**. We would be very pleased to have any additional comments by any of the witnesses that they would like to have included.

Dr. **Trivelpiece**. Thank you.

The issue that was mentioned was whether or not there should be a single program for each of our laboratories. I think the answer to that is no. There is a temptation to say that we should give each laboratory a single mission.

I think the strength of many of the DOE laboratories is the fact that they are multi-program, so I would answer that question that way. There are single-program laboratories, and they are very effective—Fermi Lab, Princeton Plasma and Physics Lab and so on.

Lead laboratory, it is tempting to do, to say that you should have one laboratory that is in charge of something. In my experience in energy research, I have found that there are some defects in that idea. I would expand on those in the additional remarks that I provide.

Do we need as many? Well, I have watched with some distress as has been mentioned earlier some of the industrial laboratories that have been affected by things that Mr. Pickens has done and other effects on causing laboratories to go out of existence. These things take 10, 15 or 20 years to put together in many cases, to reach their full effective potential.

It takes 15 minutes to take it apart and another 15 years to put it together. I would counsel thinking very carefully before any steps were taken to cause any of them to go out of existence. They are just too difficult to recreate.

What are the laboratories unique at? Well, clearly they can play a role in education, but we have a lot of universities and schools, and we should do something that augments what that is, and I think from what you have heard that is going on. Oak Ridge has a record that is as good as anyone's in that, and I will not dwell on it.

But I think it is the large facilities that permit work in small science, and you will perhaps hear of the two GEV light source at Berkeley, the six GEV light source at Argonne, the relativistic heavy ion collider at Brookhaven, we hope an advanced neutron source at Oak Ridge National Laboratory, computers at Los Alamos, computers at Livermore.

Those are facilities that are much larger than makes it sensible to have at hundreds and hundreds of places around the country. Therefore, they serve as focal points. This is a unique thing that the Department of Energy does, can do, and should be encouraged to do in the future.

Laboratories play a key role providing the facilities that advance the state-of-the-art in several areas of basic and applied technologies in ways that you cannot do in a distributed way. That is a very important issue.

In terms of the kind of things that have been done in the past, there is a temptation to say well, what are you doing for us lately in tech transfer? Nuclear power owes its existence to things that grew out of activities that took place at these laboratories. You may or may not like nuclear power, but the truth is it owes its existence to that.

In the United States, 100 million people a year receive diagnosis or therapy involving the use of nuclear medicine or its derivatives; 100 percent of that owes its existence to a term in the AEC Act which spelled out the fact that then the AEC should go forward with trying to develop activities that led to the nuclear medicine business, and it is very important. The story goes on and on.

I have never been able to prove it analytically, but I claim that probably in excess of one-third of the Gross National Product of the United States owes its existence to some very simple things: our knowledge of electrons, protons and neutrons.

A good chunk of that has grown out of the kind of research that has been supported not only at academic institutions but also at these laboratories. So if you are running a company, and you are running the IR&D committee for the company, and you asked, have you gotten a good return on what you have invested in research, the answer for the United States, its laboratories and universities, would be, damn right, we have.

Thank you.

[The prepared statement of Dr. Trivelpiece follows:]

TESTIMONY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Alvin W. Trivelpiece
Oak Ridge National Laboratory

Mr. Chairman and Members of the Subcommittee, I am pleased to have the opportunity to testify before this Subcommittee to present my views on the current operations and future mission of the Department of Energy's national laboratories and, specifically, to focus on the activities of the Oak Ridge National Laboratory. Because I served for six years as the director of the Office of Energy Research and am now the director of Oak Ridge National Laboratory, I believe I have a unique appreciation for the diversity and strengths of the Department of Energy's laboratories.

My previous testimony before this Subcommittee has made you aware how important I believe science and technology are to the economic health and well-being of the Nation. It is important that these programs be well-funded. The Department of Energy has played a pivotal role in funding this nationwide collection of activities and I believe it will continue this role in the future. DOE is a leader in energy and science and in national security. I concur with the statement made before this Committee on February 22, 1989 by Secretary of Energy-Designate James C. Watkins. He said that "the Department of Energy's national laboratories are home to some of the world's brightest and most innovative scientists and engineers. These creative minds are a precious national asset...."

The relationship between the Department and the national laboratories began to evolve in the 1940s when the Manhattan Project was expanded into the Atomic Energy Commission. In those early days, the majority of the Commission-sponsored research was performed by a complex of national laboratories through a unique contractual partnership with universities and industry. Several of the Government-owned, contractor-operated laboratories were multidisciplinary because of the need for expertise in virtually all of the sciences. This was true not only for the Manhattan Project but also later when nuclear power research became a laboratory mission. The multidisciplinary nature of the laboratories' missions expanded even more with the establishment of the Energy Research and Development Administration. Today, the DOE laboratory complex comprises the largest group of Government-owned, contractor-operated facilities in the U.S. and, indeed, the world.

The accomplishments of the Department's research laboratories are extensive, evidenced by a summary early history and some of its most notable achievements. I would like to summarize ORNL's early history and mention of a few of its notable achievements. ORNL began as a pilot plant during the Manhattan Project. Clinton Laboratories, its original name, was set up to test the plutonium production methods planned by the University of Chicago's Metallurgical Laboratory. That mission led to Oak Ridge being assigned the responsibility of building and operating a reactor to serve as a pilot plant for the large-scale production operations at Hanford, Washington. Even though it was only the second reactor ever to be constructed, it was the first to employ forced cooling, and to incorporate provisions for shielding, controls, and some other special operating requirements. Later, Oak Ridge began a program of nuclear technology education. This training course was so successful that ORNL was selected to supply trained personnel for the Atomic Energy Commission's reactor development program. The course became the Oak Ridge School of Reactor Technology. Among the graduates of this program in the early 1950s was the Secretary of Energy Watkins.

In 1955, ORNL built and then shipped an operable swimming pool reactor, then reassembled it on the grounds of the old League of Nations in Geneva for the first United Nations International Conference for the Peaceful Uses of Atomic Energy. At this conference, Liane Russell, still a member of the ORNL Biology Division, delivered a paper on studies of the effects of radiation on mouse embryos. The findings she reported resulted in a change in medical practice, as doctors became more aware of the potential hazards of x-rays on pregnant women.

ORNL constructed the first heavy-ion cyclotron and founded the field of heavy-ion physics by establishing the general properties of heavy ion elastic, transfer reactions, and compound nuclear reactions. The giant quadrupole resonance was discovered and established as a general property of nuclear matter. ORNL was the first to measure damage of reactor neutron (thermal and fast) radiation in metals and alloys. This paved the way for the development of an important area of materials science. The first measurements of radiation-induced creep were made and the importance of this phenomenon in nuclear reactor structural components was established and widely recognized in the world energy community. The world is a better place because ORNL's contributions as part of the Department of Energy. The first cyclotron especially designed to produce large quantities of radioisotopes for medical research was constructed at the Laboratory. The Department has supported the nuclear medicine industry and the medical isotope needs of customers throughout the world with ORNL's production of medical isotopes that are not commercially available.

Many significant accomplishments in the area of nuclear reactor engineering are attributable to ORNL, including the development of theories and data which are the foundation of the shield design for reactors and other radiation sources throughout the world. The design of pressure vessels has been greatly improved through applications of the theory and data from the ORNL Heavy Section Steel Program Staff were recently honored by the Nuclear Regulatory Commission for "25 years of continuous outstanding research accomplishment." The results of this program have provided an assurance of safety necessary for the light water reactor pressure vessel which has been accepted by regulatory bodies in the United States and other countries. The first major research reactor, the Materials Testing Reactor, was designed at ORNL. Reactor development is continuing beyond the High-Flux Isotope Reactor to the next generation of research reactor, the Advanced Neutron Source.

Materials science is a discipline in which ORNL research has had a significant impact. Hastelloy N alloy was developed and commercialized at ORNL for high-temperature structural service. Low-swelling, radiation-resistant alloys were invented and developed at ORNL for liquid-metal fast breeder reactor and fusion devices. The 9-Cr 1-Mo steel used in fossil and nuclear power plant structures was commercialized here. These efforts in materials development continue today with products such as the iron and nickel aluminides, which offer increased performance to assist national efforts in improved energy efficiencies.

ORNL's health and environmental research activities have had a worldwide impact. For many decades, the Laboratory has served as the prinicpal developer and reference source for models and techniques for estimating radiation doses received by humans. These models and techniques have been uniformly adopted by essentially all nations through the recommendations of the International Commission on Radiological Protection.

ORNL's research and analysis of power plant effects have resulted in both national criteria for water temperatures necessary to protect aquatic life (adopted by the National Academy of Sciences and the Environmental Protection Agency) and guidelines for the siting, design, and operation of power station condenser cooling systems.

The Department of Energy national laboratory system is composed of not only multiprogram laboratories, like those represented on this panel, but also single program laboratories like the Princeton Plasma Physics Laboratory, Fermi National Accelerator Laboratory, Oak Ridge Associated Universities, Solar Energy Research Institute, and the Stanford Linear Accelerator Center. The unique role of these laboratories in the DOE complex can be seen in the accomplishments of one, the Ames Laboratory. This facility developed the process for uranium production during the Manhattan Project. Since that time, this process has produced all of the uranium used in the western world. The ion exchange process for separating the lanthanide (rare earth) elements was developed at Ames. Worldwide recognition has been gained by Ames for its materials synthesis and processing capabilities in metals, polymers, composites and nanocrystalline materials. It produces quantities, with world-record purity levels, of over half of the naturally occurring metals and many other elements, compounds, and single crystals. These materials are requisite to forefront materials research programs in the United States and throughout the world. Ames has developed techniques and instrumentation for inductively coupled plasma - atomic emission spectroscopy and inductively coupled plasma - mass spectroscopy. These developments have revolutionized the science of analytical chemistry and resulted in major new worldwide activity.

Designated by Executive Order as a National Center for Basic Scientific Information on Superconductivity, Ames established and still publishes the High Tc Update , one of the world's leading information sources in the area of superconductivity. The first proof that the 1-2-3 high temperature superconductors (yttrium barium copper oxides) are metals was established at Ames. Ames is now patenting a unique process for the production of high temperature superconducting wires. With Iowa State University, they have established a unique technology-development, -transfer, and

-utilization enterprise which is being increasingly recognized as a model worthy of replication. Ames maintains one of the largest, if not the largest, (relative to size of the operations budget) graduate student and postdoctoral training programs in the entire national laboratory system. Approximately 175 graduate students and 40 postdoctoral associates are in residence at any time. Since its inception in 1947, Ames Laboratory has "graduated" over 1350 Ph.D. and 1000 M.S. students.

National laboratories do not exist in isolation. They have a long history of relationships with the university and industrial communities through a variety of mechanisms. Some laboratories have particularly close relationships with universities because their operating contractor is a university or university consortium. Large numbers of university faculty and students (sometimes up to 20% of the full-time equivalent staff) work for extended periods at almost all the labs. Other kinds of relationships have also been developed. The University of Tennessee, Knoxville, and the Oak Ridge National Laboratory are collaborating on a joint Distinguished Scientist program among a host of joint ventures.

Laboratory relationships with industry have also been significant. The history of the development of the nuclear power industry is but one example of the fruits of such relationships. Currently, relationships take the form of subcontracting with industry for technical and engineering analyses and component and hardware development, and participation by industrial scientists on DOE laboratory advisory and peer review groups. Today industry personnel and Laboratory staff work side by side to solve common problems using DOE user facilities. Several facilities merit particular mention. The Combustion Research Facility at Sandia-Livermore facilitates laser diagnostics studies of combustion systems. The National Synchrotron Light Source at Brookhaven National Laboratory serves the physics, materials, chemical and biological research communities. Industrial users have contributed to the NSLS by building beam lines to meet specific research needs. IBM has built a special beam line to conduct research on x-ray lithography, a process of great potential in the production of computer chips. These industry-funded beam lines are also made available for a portion of the time to the general research community.

To continue, at Oak Ridge National Laboratory, cooperative arrangements have resulted in a Roof Research Center complex that is partially funded by industry. Our capabilities in roof research are enhanced by a large-scale climate simulator which we are using in tests for Attic Seal, Inc., a small innovative roofing company. This user facility can measure performance of attic insulation products in one day for a range of temperatures representing all seasons and all locations in the United States. Increased knowledge of the thermal efficiency of insulating materials will lead to reduction in heating and cooling requirements of residential buildings. In another activity conducted at the facility, the Society of the Plastics Industry and the Polyisocyanurate Insulation Manufacturers Association, the National Roofing Contractors Association and ORNL are studying the impact of replacing CFCs in foam insulation boards. These CFC-based products have a 60% share of the flat roofing market and currently provide substantial energy savings benefits. Before the industry switches to alternative products to reduce the ozone depletion potential believed to be connected to the use of CFCs, these strategies must be tested for thermal and mechanical acceptability.

Within this fiscal year, the High Temperature Superconductivity Pilot Center at ORNL has increased to a total of 15 its number of cooperative agreements with industry. Industry is sharing more than half of the costs in this program. This shows the potential of the laboratories in working with industry in the materials science areas. Other recent achievements include signing a patent license agreement on plasma-etching technology with SEMATECH and a collaborative agreement with Garrett Ceramic Components, Inc., for research on gelcasting.

The Oak Ridge Detector Center was established this fiscal year as an interface organization with detector collaborators from universities, industries, and foreign countries. ORNL will be a major U.S. base for the research, design, integration, and construction of the Lone Star (L*) detector, one of the detectors proposed for the Superconducting Super Collider.

Over the years, the national laboratory system and its programs have been the subject of several reviews. At the request of the Deputy Secretary in 1981, the Energy Research Advisory Board examined the roles of the national laboratories (Final Report of the Multiprogram Laboratory Panel, Energy Research Advisory Board, September 1982). I testified on "The Future of the Department of Energy's Multiprogram Laboratories" before the House of Representatives Committee on Science and Technology, Subcommittee on Energy Development and Applications, and the Subcommittee on Energy Research and Production on December 2, 1982. ERAB found that, "The multiprogram national laboratories complex constitute an impressive national and research and development asset. Moreover, it possesses capabilities for the performance of large-scale, long-term, high-risk, multidisciplinary research and development." They also made several recommendations, such as continuing review of the roles and missions of the laboratories, improvement of the institutional planning process, and increased cooperative use of facilities by universities and industry.

Several other reviews of the national laboratories have focused on similar issues. Ensuring that governmental research and development establishments are assigned significant and challenging work, simplifying management controls, and giving laboratory directors more authority to command resources and make administrative decisions was also mentioned in the Bell report to the President in April 1962. To make effective use of the technical and management capabilities in the field by increasing the delegation of program execution authority to the field is a recommendation of the December 1975 report to the Field and Laboratory Utilization Group that was convened at the beginning of ERDA. These are reports are all referenced in "The role of the National Laboratories in Energy R&D", Hearings before the House of Representatives Committee on Science and Technology, Subcommittee on Fossil and Nuclear Energy Research, Development and Demonstration, November 2, and 3, 1977 and May 16, 1978. The recommendations of the sixties and seventies are consistent with what ERAB has concluded.

While I was Director of the Office of Energy Research, I was involved in an assessment of the Office of Basic Energy Sciences Program. Out of approximately 1200 active projects, a sample of 129 projects was selected for review by panels of scientific peers (An assessment of the Basic Energy Sciences Program, Report DOE/ER--0123 V 1 and 2). The panels rated individual projects on the basis of quality of science, quality of the project team, and probable impact on the Department's mission.Overall, the peer review panels gave this program high ratings in quality of science, quality of project team, and mission impact. Based on ratings of the sample projects, the peer review examination found a large percentage, about 60%, of active projects to be of high quality overall; indeed, 10% were rated to be of exceptional excellence. Only a small fraction, about 10%, were judged as having significant shortcomings.

The President's Private Sector Survey on Cost Control in their "Task Force Report on the Department of Energy, the Federal Energy Regulatory Commission, and the Nuclear Regulatory Commission" (April 15, 1983) recommended several initiatives relating to missions, laboratory management, increased participation and collaboration with private industry.

George Keyworth, the President's Science Advisor, established the Federal Laboratory Review Panel to review the federal laboratories and to recommend actions to improve their use and performance. Chaired by David Packard, this Panel in their report ("Report of the White House Science Council", May 1983) made recommendations concerning mission; personnel; funding; management; and interactions with universities, industries and users.

Recommendations assessing national needs have been prepared by several review committees. Several reports have focused on the needs of the materials science community. At the request of George Keyworth, the National Research Council prepared a report on the priorities for major materials facilities (Major Facilities for Materials Research and Related Disciplines, Major Materials Facilities Committee, Commission on Physical Sciences, Mathematics, and Resources, National Academy Press, 1984) . Under the direction of co-chairmen Frederick Sietz and Dean Eastman, the Committee recommended construction of a 6-GeV Synchrotron Radiation Facility, an Advanced Steady State Neutron Source Facility, a 1-2 GeV Synchrotron Radiation Facility, and a High-Intensity Pulsed Neutron Source Facility. These recommendations were reiterated by a recent National Research Council report (Materials Science and Engineering for the 1990s, Maintaining Competitiveness in the Age of Materials, Committee on Materials Science and Engineering, National Research Council, National Academy Press, 1989).

On October 2-4, and 22-24, 1985, the Task Force on Science Policy of the House of Representatives Committee on Science and Technology held hearings on "Science in the Mission Agencies and Federal Laboratories." I testified on these activities relating to the Department of Energy and its relationship with the federal laboratories.

The Department of Energy and its contractors have been recognized as leaders in our national R&D effort. In the 1989 competition, the Department of Energy laboratories and facilities won 18 R&D 100 awards. It is no accident for this organization to be recognized as producing this many of the 100 most significant technical developments in the previous calendar year. Neither was this just a single occurrence. Over the previous 26 years, the Department and its laboratories have received more than 250 awards, with Argonne and ORNL among the top eight award winners.

The magazine High Technology Business, in its November-December 1989 issue ("Technology hits and misses of the 1980's"), features three results from Department of Energy research in the twenty key technology developments of the last decade: ORNL's nickel aluminide alloys and whisker-toughened ceramics and Brookhaven's National Synchrotron Light Source. ORNL and the other facilities of Martin Marietta Energy Systems have 44 license agreements in effect as of July 1, 1990. These have generated royalties in excess of $1.1 million and product sales of about $27 million.

In his July 6, 1990, memorandum to directors of Department of Energy laboratories, Secretary Watkins provided policy guidance for the FY 1991 through FY 1996 institutional planning process. He highlighted several objectives needing integration: "Technology transfer is a mission for the National Laboratories and the DOE. High priority on making the Department's resources available to improve mathematics and science education...consider the opportunities that exist to address challenges in environment, safety, and health...." Several efforts in these areas are of particular interest.

Technology transfer efforts throughout the Department are important to the Department's mission. Recent accomplishments in technology transfer from DOE and its laboratories have been highlighted in the Department's publication Technology '89. This publication provides summaries of technology transfer highlights from the previous year and ways for industry and universities to interact with both the multiprogram and single program laboratories.

According to July, 1990 issue of DOE This Month, scientists from Brookhaven, ORNL, and Sandia were the latest announced winners of Federal Laboratory Consortium Awards for Excellence. At Brookhaven, Leonard Hamilton and Paul Moskowitz were cited for their work with the photovoltaics industry, identifying health and safety hazards, as well as risk management approaches for new manufacturing materials. Brookhaven's Meyer Steinberg was honored for his efforts in promoting industrial acceptance of HYDROCARB, a novel process for making clean carbon fuels. Pete Witze and Elson Porter of Sandia-Livermore were recognized for initiating a partnership with industry leading to commercialization of a fiber-optic-instrumented spark-plug probe for seeing inside auto engines while they are running. Bob Blewer of Sandia-Albuquerque was recognized for his role in the development of technology for use in chemical-vapor-deposited tungsten and in transfer of the technology for use in commercial microelectronics processes and products.

ORNL's Victor J. Tennery was honored for conceptualizing, starting, and managing the High-Temperature Materials Laboratory. Users represent more than 80 universities, industrial firms, and other government facilities. In FY 1989, external use amounted to a total of 581 industry, 248 university, and 9 other government laboratories user days. In addition, there were 31 proprietary user days of the facilities at full cost recovery. HTML is showing increased activity during this fiscal year.

Last year, more than 15,000 students participated in ORNL educational programs. Many of these students are in precollege activities designed to spark interest in science and mathematics education. Programs and activities were presented at our Ecological and Physical Sciences Study Center. Last week, I met some of the students that participated in the DOE High School Honors Program at ORNL. They represented all states and several foreign countries. Each of the national laboratories participating in this program focuses on a different subject. At ORNL, the students study environmental sciences for their two-week period. We have programs for high school and college teachers, high school and college students, and joint graduate programs with The University of Tennessee, Knoxville, in biomedical and environmental sciences. ORNL is continuing to expand our contacts within the minority educational community. For example, we are participating with the Science and Technology Alliance, along with Sandia and Los Alamos National Laboratories in an effort to increase the representation of Blacks, American Indians, and Hispanics in DOE's scientific and engineering programs. We have also adopted Vine Middle School in Knoxville, a predominantly Black institution as part of Secretary Watkins Adopt-A-School program. A recently signed joint agreement between the Department of Energy and the Appalachian Regional Commission will provide educational experiences at ORNL for students and teachers. An agreement, between DOE and Coca-Cola also involves ORNL and Washington, D.C. high school students. Martin Marietta Corporation has committed $1 million for a three year program with The University of Tennessee, Knoxville, to enhance science and mathematics education in this area.

Environmental research and development is an important research area at ORNL. The diversity of the research program can be seen through several examples. Through our Carbon Dioxide Information Analysis Center, ORNL has become a center of expertise in the investigation of the effect of increasing carbon dioxide and changing climate on natural and societal resources. The Center's data holdings include such diverse information as tree-ring chronologies, surface air temperature anomalies, and atmospheric carbon dioxide concentrations. The Center has recently been asked to apply for certification as World Data Center A. If successful, this would be the first time since 1956 that this designation has been awarded.

ORNL has founded the concept of "systems ecology," using mathematical models to integrate information on radionuclide transport in ecological systems both on land and in water. This was diversified to include contaminants and other features of the growth and energy budgets of ecosystems. Our ecologists took the lead in the environmental impact analysis for the National Environmental Policy Act environmental impact statements for nuclear power plants, including the full range of nonradiological and radiological issues. During the 1960s, pioneering studies were performed at ORNL on the radionuclide transport in terrestrial plants and waterborne transport of radioactive contaminants down the Clinch River. Revelations of mercury contamination and other environmental ills on the Oak Ridge Reservation again involved the ORNL scientists in monitoring and testing local effluents for toxicity. The Laboratory provided rapid and extensive assistance during the Three Mile Island incident making, chemical, and isotopic measurements. ORNL developed the process for the cleanup of the water from the containment building.

The use of the major research performers -- federal laboratories, universities, and industry -- has resulted over the years in a balanced approach aimed at using the best performer for a given task. The private sector provides technological advances of interest to the marketplace in close cooperation with the national laboratories. Long-term research in the national interest beyond what can be expected from private industry is an appropriate federal role. It is important to maintain core basic and applied research programs in the laboratories, particularly in situations where capital-intensive equipment is required, long-term research is involved, or where research aimed at developing new energy technologies involves large uncertainties or important energy-related environmental factors.

The importance of university involvement is stressed in two ways: developing new and innovative scientific and technical concepts, and preparing and training students. Our commitment to training students for future science and engineering careers extends to the precollege level.

Both the universities and the laboratories are key links to the transfer of technology to the private sector. This transfer of knowledge, and ultimately, technology into use in the private sector where it can contribute to the nation's economic health and well-being and national security is our overriding goal. Through the Department's R&D Laboratory Technology Transfer Program, managed by the Office of Energy Research, and legislation like the National Competitiveness Technology Transfer Act. My colleagues in other facilities in Oak Ridge are enthusiastic about the Advanced Manufacturing Initiative agreement announced on July 18, 1990, by Secretary Watkins. Success in initiatives of this type, the user facilities, the High-Temperature Superconductivity Pilot Center concept, with the serendipity available at the national laboratories, will benefit not only technology transfer but our national competitiveness, as well.

There is immense value to the nation in the R&D programs supported by the Department of Energy and of the R&D performers who carry them out. Other major contributors that are not recognized as frequently are the Department of Energy staff who provide the long-term programmatic direction for these activities. I appreciate their dedication and service to this national mission.

Senator BINGAMAN. Thank you very much.

Dr. Shank from Lawrence Berkeley Laboratory. Thank you for being here.

STATEMENT OF DR. CHARLES V. SHANK, DIRECTOR, LAWRENCE BERKELEY LABORATORY

Dr. SHANK. My name is Charles Shank. I am Director of the Lawrence Berkeley Laboratory, having assumed this position last September, after 20 years in research and management at AT&T Bell Laboratories. My experience in industry and my interactions with the DOE national laboratories provide me with a strong belief in their usefulness, and I wish to share that with you this morning.

Lawrence Berkeley Laboratory is a multi-program laboratory with a budget of approximately $230 million. Our research ranges from high-energy physics to new materials, and sequencing the human genome. We have 3,200 staff, 220 of whom are also faculty at the University of California at Berkeley Campus. LBL, as I have discovered since last September, is certainly one of Secretary Watkins' jewels in the crown of the Federal system.

With its foundation in basic research, LBL is a valued fundamental science resource that needs to be used effectively. LBL also has an historic role in science education. We have over 500 graduate students pursuing degrees through DOE-sponsored research.

We also have new programs that make the LBL research experience available to undergraduate and pre-college students and teachers. For over two generations, LBL helped to educate America's scientists and engineers. We are proud of that role, and we are excited about the future opportunities.

As this Committee is aware, energy will be a critical issue in the coming decade. In response to the energy crises of the 1970's, Lawrence Berkeley Laboratory established the Nation's premier energy efficiency building program. LBL researchers have pioneered advances in energy-efficient windows and lighting that save American consumers hundreds of millions of dollars each year.

With peace breaking out, we have the opportunity to advance energy efficiency in Eastern Europe and the developing countries. LBL has developed national energy databases and models that provide analysis of factors influencing energy demand around the world. Together with LBL's technology innovations, this knowledge has led to improvements ranging from better stoves in India to better buildings in Indonesia. LBL resources are correctly brought to bear in this essential effort.

Earth sciences research at LBL has helped identify specific resource sites and maximize their efficient recovery. Our work is used by both petroleum and geothermal industries. Our collaborations with these industries have led to the development of new geophysical exploration technology.

We have also been using this experience to help solve the problem of the permanent disposal of nuclear waste. Our Nation's hazardous waste problem is a prime opportunity for the national laboratories to assist in the cleanup of these sites. LBL devised the solution to the problem of selenium contamination of the Kesterson Wildlife Refuge for the U.S. Bureau of Reclamation.

We are now using this expertise on a more complex problem at a wildlife refuge in Nevada. In both cases we are finding that meticulous research will yield the most complete and cost-effective solution possible.

Since the days of the Atomic Energy Commission, national laboratories have had a special role in energy-related biological research. LBL is often called the birthplace of nuclear medicine, with pioneering work in medical imaging and the use of particle beams to treat various types of cancer.

Today we are continuing to advance this technology at LBL where scientists have developed the highest resolution positron emission tomography machine in the world. Cancer treatment using heavy ions only available at LBL has been 80 percent to 90 percent successful at treating prostate and salivary gland tumors. Research is continuing on treating other types of cancers as well.

The long-term goal, of course, is prevention. Some cancers and more than 4,000 diseases are genetically based. Learning more about our genetic makeup is the goal of the human genome project.

The subcommittee heard last week from Dr. Charles Cantor of LBL's Human Genome Center about our progress and plans for the future. As one of three DOE Human Genome Centers, LBL is proud to have a major role in this project.

LBL research on heavy ions has consequences far beyond patient treatment. These particles are the closest thing to cosmic rays that may pose a health hazard for long-term manned space flight. One estimate is that on a 1,000-day mission protected by today's shielding, more than 10 percent of astronaut's brain neurons could be damaged by these particles.

Joint NASA/LBL research is examining the fundamental effects of radiation on human tissue. If long-term manned space flight is to be an important part of NASA, we need to fully understand all potential health risks.

LBL operates a number of DOE National User Facilities. These are unique scientific facilities operated for researchers from universities, industries, and other laboratories. The construction and operation of these facilities has been a service worthy of national laboratories.

LBL is currently constructing one of the newest National User Facilities, the Advanced Light Source. The ALS is a $100 million facility that will provide the world's brightest source of soft x-rays for research in such areas as material science, combustion chemistry, structural biology, and projection photo-lithography.

When it begins operation in 1993, a new era in research will begin for LBL and the world. The Advanced Light Source will provide an opportunity for research centers in combustion chemistry and life sciences. The Combustion Dynamics Facility, a joint LBL/Sandia proposal, would explore the fundamental chemistry involved in combustion. The ultimate goal of this research is cleaner, more efficient combustion processes.

Having the Advanced Light Source will also allow us to do biological research never before possible. LBL's proposed ALS life sciences center will permit users from around the Nation to image biological samples for the first time in their unaltered state.

DOE has a tradition of supporting basic energy and defense research at its national laboratories. But there has not been sufficient attention to connect the advances in fundamental science to revolutionary changes in technologies that could impact our economy. Currently, there is no DOE program that directs the tools and methods of fundamental science towards major activities in critical technologies.

This technology research depends on the same skills, insights, and unique facilities as basic research. And like basic research, has a long-term payoff. Technology research, in my view, is the missing link the Department of Energy's research program that would ensure that America's industry obtains the benefit of the Nation's investment in DOE research.

Coming from Bell Laboratories, I can testify firsthand to the devastating impact the short-term corporate view has had on American industrial research. As a member of the National Critical Technology Panel appointed by Dr. Bromley, I plan to urge support for many of these critical technologies.

Supporting critical technology research does not mean establishing an industrial policy. The goal of technology research is to add long-term value to the American industry without distorting the economy. The fundamental character of these efforts makes these projects precompetitive. As marketable results arise, industrial participants could take these results and begin competitive product development.

An example is on research on the next generation of x-ray photolithography. Critical to this process are advanced optical elements that can focus soft x-ray beams. LBL's Center for X-Ray Optics has developed special lenses and mirrors with the diameter of less than a human hair to focus x-ray onto semiconductor chips.

The next step would be to use the Advanced Light Source for projection x-ray photo-lithography research with these mirrors. The problem is that while DOE supports mirror development at the ALS research center, they do not support industrial-related technology research. We have an ideal tool in the ALS, the ideal people in our Center for X-Ray Optics, but no way to use these advantages to benefit our economy.

In testimony today I have outlined our current research in LBL and how it will lead to the future directions of our laboratory and the Department of Energy. The logical question is what will it take to get from here to there.

First and foremost is the continuing commitment to the support of basic research at national laboratories. The Committee is to be congratulated for its recognition of the importance of basic research, as it is the source of fundamental knowledge behind all new initiatives.

An equally important commitment is to maintain a strong staff and facility capabilities at the national laboratories. We cannot ask leading scientists to perform 1990's research in 1940's buildings. New scientific facilities and equipment are essential to advance research and maintaining the highest environment and safety standards. DOE should establish a facilities modernization program for its energy research national laboratories.

Maintaining a first rate scientific enterprise is uppermost in my mind as a director. That is why I am dismayed by the recent House action to eliminate exploratory research and development programs at national laboratories. These small but essential programs have been used over the years to support innovative scientific ideas at their earliest exploratory stage.

The authority has also allowed us to respond quickly to new scientific challenges and opportunities. A good example is discovery of the new high temperature superconductors. With exploratory research and development funds, we were able to begin programs that have already made contributions. Without this flexibility, opportunities would have been lost. I urge the committee to support continuation of these programs.

The lack of a mechanism for support of technology research remains a concern. Although Congress is to be congratulated for establishing the advance technology program in the Department of Commerce, it is not enough. I recommend that the Department of Energy establish its own office of technology research to provide specific funds for technology research in its national laboratories.

Finally, our economic future depends on mutual outreach between corporations and national laboratories. Technology research will only have a significant impact if we can move the people with the knowledge of advanced technologies to industry. This may mean industrial scientists working in our laboratories and incentives to move national laboratory scientists into industry. The earlier that industry is involved, the smoother the transfer of the fruits of technology research.

I hope that my remarks provide some insight about how the Department of Energy national laboratories can benefit our country. They are a unique resource and, with the structural change in our economy, more essential than ever before. With your continued support, they will be an important part of our national economic development into the 21st century.

[The prepared statement of Dr. Shank follows:]

Written Statement of Charles V. Shank
Director, Lawrence Berkeley Laboratory
before the
Senate Energy and Natural Resources Committee
Energy Research and Development Subcommittee
Wednesday, July 25, 1990

Mr. Chairman, it is a pleasure to testify before the Subcommittee today. My name is Charles Shank. I am the director of the Lawrence Berkeley Laboratory, having assumed this position last September after twenty years in research and management at AT&T Bell Laboratories. My experience in industry, which included some interactions with the DOE national laboratories, provides me with a strong belief in their usefulness that I wish to share with you this morning.

Let me first give you a brief profile of the Lawrence Berkeley Laboratory. LBL was founded in 1931 by Ernest Lawrence in Berkeley, California as the world's first particle physics laboratory. Today we are a multiprogram laboratory with a FY 1990 budget of approximately $232 million. Our research ranges widely from high energy and nuclear physics to new materials, structural biology and reservoir engineering. We have 3200 staff, 220 of whom are also faculty on the UC Berkeley campus. Their outstanding work over the years has won international acclaim, including nine Nobel Prizes. LBL, as I have discovered since last September, is certainly one of Secretary Watkins' "jewels in the crown" of the Federal system.

With its foundation in basic research and the development and operation of unique user facilities, LBL is a valued fundamental science resource that needs to be used more effectively. The state of the economy - a mounting Federal deficit, corporate restructuring and the resulting shrinkage in corporate R&D, international economic competition - requires that Federal research and development investments be utilized in support of national economic security.

LBL also has an historic and expanding role in science education. We have over 500 graduate students pursuing their advanced degrees through DOE-sponsored research. We also have new programs that make the LBL research experience available to undergraduate and precollege students and teachers. For over two generations, LBL has helped to educate America's scientists and engineers. We are proud of that role, and are excited about the opportunities to expand that effort in the coming years.

The laboratories represented here today were creations of the Atomic Energy Commission, and are today part of the Department of Energy. But we are also national laboratories, with resources and ideas that can benefit the entire nation. It is time to put these resources to work and explore all the opportunities that the scientific enterprise provides.

Energy, the Environment and LBL

Today I'd like to talk about how LBL's current research efforts will lead in future directions and how we can mobilize the national laboratories for the good of the nation. As this Committee is well aware, energy supply and demand is likely to be a more critical issue for our nation in the coming decade. We are, once again, importing half the oil we use, with the resulting national security implications. Our refining capacity is almost saturated, but there is little likelihood of new construction. As the price of energy has stabilized, and actually dropped in real terms, per capita energy use has begun to rise. This Committee is more familiar than most with these sober facts, and is to be congratulated for your continuing attention to the world energy situation.

In response to the energy crises of the 1970's, Lawrence Berkeley Laboratory began what is today the nation's premier energy-efficient buildings program. LBL researchers have pioneered advances in energy-efficient windows and fluorescent lighting that now save the American consumer billions of dollars a year in energy costs. Both of these programs, working closely with industry, continue to introduce even more efficient innovations with lower operating and manufacturing costs.

Another area of energy conservation technology development at LBL has been in advanced batteries for electric vehicles and utility peak power storage. Recent research on a zinc-nickel oxide cell could result in vehicle batteries that are half the weight of current systems and with a system life 3-4 times longer than current zinc-nickel cells. The Laboratory is advancing new battery technology as a coordinated effort with automobile manufactures and with electric utilities. The plan is to develop a system which could lead to a substantial electric vehicle fleet in the 21st century - an essential energy and environmental goal. Recent actions by the Southern California Air Quality Management District and General Motors may accelerate the development and use of this technology.

With "peace breaking out", our nation has the opportunity to advance energy-efficiency in Eastern Europe and the developing countries. It is in our own best interest that these countries build the most energy-efficient economies possible. LBL, working with the Agency for International Development, has developed national energy data bases and models that provide an in-depth analysis of factors influencing energy demand in many areas of the world, including the Soviet Union, China, India, Egypt and Brazil. Together with LBL's technology innovations in building and appliance design, this knowledge has led to improvements in standards and efficiency ranging from better stoves in India to better commercial buildings in Indonesia. We have the technology, and the expertise, that can make these nations more productive in the world economy. A short-term investment in transferring this knowledge and technology to these nations will pay long-term dividends in the stability of energy supply and price. LBL resources should be brought to bear in this essential effort.

In developing both conventional and alternative energy supplies, fundamental earth sciences research at LBL has contributed to identifying specific resource sites and maximizing their efficient recovery. Our work in imaging what's below the earth's surface, and how fluids and heat move through that world, has been used by both the petroleum and geothermal industries in the further development of their resources. Our collaborations with both of these industries has resulted in the development of new geophysical exploration technology. We have also been using this expertise to help find a solution for the permanent disposal of nuclear waste.

Our nation's hazardous waste problem is a prime opportunity for the national laboratories to use their capabilities, built up through existing DOE programs, to assist in the essential cleanup of these sites. LBL developed a cost-effective solution for the problem of selenium contamination of the Kesterson Wildlife Refuge for the U.S. Bureau of Reclamation. We are now using this expertise on a similar, but more complex, problem at the Stillwater Wildlife Refuge near Reno,Nevada. In both cases, we are finding that meticulous research on the root causes of the problem, along with a detailed examination of all possible solutions, will yield a solution that is more complete and cost-effective than otherwise possible. In the specific case of Kesterson, LBL research resulted in a $10 million solution that is more comprehensive than the $100-150 million solution initially proposed.

Now we have proposed moving this expertise to one of our nation's most massive and challenging waste problems - cleaning up our nuclear weapons complex. The Administration and the Congress both deserve credit for recognizing the extent of the problem and for dramatically increasing the resources necessary to do the job. We at LBL have a commitment to apply our geophysical and geochemical expertise to cleanup contamination from government facilities and to assist industry efforts in both waste cleanup and future waste minimization. LBL's subsurface imaging capabilities can provide three dimensional images of contaminant flow. New techniques such as foam flushing, offer the potential to sweep some contaminants from the underground environment. Our multidisciplinary experience suggests that an integrated and comprehensive approach to this problem is most promising. We have proposed a plan to DOE's Environmental Restoration and Waste Management Office that would utilize this approach, and would allow LBL's expertise to benefit this national effort.

Health Research at LBL

Cleaning up our environment is critical to the maintenance of our nation's health. From the first days of the Atomic Energy Commission, to today's Department of Energy, the national laboratories have had a special responsibility for energy-related biological research. Much of the early work was in the medical uses of radiation. LBL is often called the birthplace of nuclear medicine, with pioneering work in medical imaging using positron emission tomography and in the use of particle beams to treat various types of cancer. Today we are continuing to advance technology in these areas. LBL scientists have developed the highest resolution positron emission tomography machine in the world. In particle beam therapy at the Bevalac, cancer treatment using heavy ions only available at LBL continues to improve the treatment of some forms of cancer. We are also working with Loma Linda University in Southern California, sharing our expertise as they construct and begin operation of the world's first proton accelerator expressly designed for cancer therapy.

As we work to advance cancer treatment, ahead of us lies the long-term goal of cancer prevention. Some cancers, and more than 4,000 diseases, are genetically based. Learning more about the human genetic makeup will allow us to explore the possibility of preventing those diseases. This is the ultimate goal of the Human Genome Project. The Subcommittee heard last week from Dr. Charles Cantor of LBL's Human Genome Center, in some detail about the progress we have made and our plans for the future. This is an ambitious project that, when completed will have sequenced the 3 billion base pairs that make up a human being in a timely, cost-effective manner. As one of three DOE human genome centers, LBL is proud to have a major role in this project. Our expertise in biology, computer science and technology development will greatly contribute to meeting the ambitious goals of this project.

LBL's strengths in biological research, complemented by the capabilities next door at UC Berkeley, is breaking new ground in the growing field of structural biology. We now understand at the molecular level the active sites of attachment and control of some cancer causing proteins, work that is receiving close attention by the pharmaceutical industry. The structure of antibodies is also being understood and modified, so that these highly adjustable molecules can be used as catalysts to speed the development of new synthetic products. Research in this area in the decades ahead, using new analytical and imaging tools never before available to biologists, will elucidate the structure and potentially repair the function of the smallest underlying biological systems. Much of this work will be critical to the future of America's biotechnology companies. LBL's location in the San Francisco Bay Area, home to a large number of established biotechnology companies, provides us a natural opportunity to work with these firms in the pursuit of a healthier and more productive life for all Americans.

LBL research on the health effects of heavy charged particles has consequences far beyond patient treatment. Those charged particles created at LBL's Bevalac are the closest thing to cosmic rays that may pose a potential health hazard for long-term manned space flight. One estimate is that on a 1000-day mission, protected by today's spacecraft shielding, more than 10% of an astronaut's brain neurons would be hit by these particles, which are thought to be energetic enough to cause some form of cell injury. Joint NASA-LBL research at LBL's Bevalac accelerator is examining the fundamental effects of radiation on human tissue. The Bevalac is a nuclear physics accelerator originally built in the 1950's, and is unlikely to be operated by the Nuclear Physics program past the mid-1990's. Both LBL, NASA and the Department of Energy are exploring ways to continue this critically important research. If long-term manned space flight is to be an important part of NASA's future mission, it is our responsibility to fully understand all the potential health risks associated with this venture.

Scientific Facilities and Advanced Instrumentation

LBL operates a number of DOE's national user facilities; forefront scientific facilities, often unique in the world, operated by national laboratories for scientific users from universities, industries and other national laboratories. The construction and operation of these facilities, most of which are too large for a university campus, has been a national service worthy of national laboratories. With the increasing sophistication of science has come an increasing number, and complexity, of these forefront scientific facilities.

The accelerator expertise that LBL has acquired over the years, beginning with Ernest Lawrence and his invention of the cyclotron, has given us the capability to construct the world's most advanced source of soft x-rays, the Advanced Light Source. Currently under construction at LBL, the ALS is a new $100 million national user facility that will be useful for research in areas as diverse as materials science, combustion chemistry, structural biology and x-ray lithography. When it is commissioned in 1993, a new era in fundamental research will begin for LBL and the world.

The multidisciplinary nature of national laboratories like LBL is not only illustrated by the broad areas of fundamental science at our user facilities but by the varied types of advanced instrumentation we develop. Here again, expertise can cut across fields to benefit varied scientific disciplines. Our work in developing the world's highest resolution microscope, at LBL's National Center for Electron Microscopy, has helped other microscopy work at the

Laboratory - and led to proposals for an even-higher resolution microscope. LBL is developing more powerful uses for nuclear magnetic resonance imaging, for both materials science and biomedical research, that have received technology achievement awards from the Industrial Research Institute. Computer and electronics expertise has allowed LBL to move from its invention in 1959 of the bubble chamber for imaging nuclear collisions to the development of the premier detector at SLAC - the Time Projection Chamber.

Advanced instrumentation will also allow the Advanced Light Source to provide unique opportunities for establishing dedicated research centers in combustion chemistry and the life sciences. The Combustion Dynamics Facility, a joint LBL-Sandia proposal, would combine the strengths of the two institutions in exploring the fundamental chemistry involved in the combustion process. Modern chemical dynamics is a powerful tool with broad implications. The new tools available at the CDF will advance this field not only in support of DOE's energy mission but for fundamental understanding as well. At LBL, using a combination of the ALS and a unique free electron laser, we will be able to isolate and determine the nearly instantaneous combustion reactions at the atomic level. Together with other advanced lasers and computational equipment, national users will have the opportunity to discover the mechanisms and intermediate reactions in fuel burning and pollutant formation. However, the ultimate goal of this research is a cleaner, more efficient combustion process.

Having the Advanced Light Source at LBL will also allow us to perform biological research never before possible. As part of LBL's proposed ALS Life Sciences Center, an integral part of DOE's Structural Biology Initiative, the x-ray beams of the ALS will allow users from around the nation to image biological samples in their unaltered state. Previous imaging techniques have required drying, staining and otherwise distorting the samples, thereby reducing their usefulness in research. The tunability of the ALS allows short wavelength light to penetrate through the water and to selectively image the carbon and nitrogen molecules that comprise biological structures. The ALS will also produce high energy x-rays that will allow biologists to examine crystallized macromolecules for structural resolution of individual atoms.

The ability to collect and represent massive amounts of data is equally important for high energy physics. The Superconducting Super Collider (SSC) will be coming online at the end of this decade, with the need to examine the results of 100 million interactions per second. This massive amount of data identification, handling and analysis will require the combined talents of many disciplines, and the detector development expertise of the national laboratories. LBL was the host for the original design group for the SSC. Today LBL scientists are the leaders in a multi-institution, multi-nation collaboration that is proposing a major detector system for the SSC.

The Solenoidal Detector Collaboration (SDC) draws on LBL's experience from the first days of accelerator physics to the development of the most complex detectors available today. A decision to move forward with this detector system, expected within the next two years, would mean a major role for LBL in its final design, construction and operation, continuing LBL's leading role in man's search to understand the nature of matter.

Technology Research - the Missing Link

DOE has a long tradition of supporting basic research at its National Laboratories in scientific fields relevant to energy and defense. In the DOE fundamental science programs, there has not been sufficient attention to connect advances in fundamental science to revolutionary technologies that could impact our economy. At the same time, DOE's energy technology programs focussed primarily on incremental advances of current systems. There is no program in DOE that directs the tools and methods of fundamental science towards major advances in the performance of critical technologies. This "technology research" depends on the same skills, insights and unique facilities that basic research requires and, like basic research, has a long-term payoff. By building on scientific advances, it can clarify possible applications and demonstrate uses. Modern high technology research is a complex endeavor requiring the resources and access to facilities which exist only in the DOE laboratories. Technology research is not only the missing link in the Department of Energy's programs but it is also absent in American industry. It is, however, something that Japanese industry and government have learned to do very well

Coming from AT&T Bell Laboratories, I can testify first-hand to the impact that the short-term corporate view has had on the research capabilities of American industry. Many companies have shut down their entire research operations, while others have greatly scaled back. Previous corporate definitions of long-term vision have been revised to cover, in most cases, what can improve a specific product within the next year. Our national economic strength requires support of this intermediate step in the research and development process - support that would complement, and not compete with, R&D carried out by corporate America. As a member of the National Critical Technologies Panel, appointed by Dr. Bromley, I plan to urge that this support be provided for many of the critical technologies in which our country's lead is rapidly diminishing.

Let me emphasize that choosing to support research on critical technologies does not mean choosing an industry or even an industrial policy. The fundamental character of these efforts essentially makes these projects pre-competitive. The goal of technology research is adding long-term value to American industry without distorting the economy. As marketable results arise, industrial participants could withdraw and begin competitive product development. An example of this is research to develop the next generation of x-ray lithography processes. Critical components of such processes are advanced optical elements that can focus and redirect soft x-ray beams. With limited DOE support, LBL's Center for X-Ray Optics has worked on the development of special lenses and mirrors, with a diameter less than a human hair, to focus x-rays to a point small enough to etch onto semiconductor chips. The next step in this process would be to use the Advanced Light Source under construction at LBL, with the ideal spectrum of x-rays, for x-ray lithography research using these mirrors. The problem is that while the DOE can support the mirror development in the context of supporting ALS users, they do not have a specific mission to support industrially-related technology research. We will have the ideal tool in the ALS - the ideal people in our Center for X-Ray Optics - but no current way to use these advantages for the greater benefit of our economy.

In passing the National Competitiveness Technology Transfer Act, the Congress broadened the mission of the Department of Energy and its Laboratories to include technology transfer. The concept of technology research is ideally suited to the DOE Laboratories. Their foundation of basic research, and their multidisciplinary teams, needs only the collaboration of industrial scientists and managers to choose the critical technologies and establish performance goals at a level that requires revolutionary innovation.

The Future of Our National Laboratories

In my testimony today, I have outlined some of the current research at LBL, and how that research will lead to future directions for our Laboratory and the Department of Energy. The logical question now is: what will it take to get there from here?

First and foremost is a continuing commitment to the support of basic research at the national laboratories. A disturbing trend over the last decade has been the advancement of new initiatives and new facilities at the expense of support for the fundamental research that led to the advance. Within DOE, this trend is seen most alarmingly in the DOE Basic Energy Sciences budget. When the large new initiatives are removed, the FY 1991 budgets have not kept up with inflation. This Committee is to be congratulated as one of the few in Congress which has recognized over the years the importance of basic research. Please continue to recognize the essential need to preserve the basic research base that provides the fundamental knowledge to advance all the new initiatives.

An equally important commitment is to maintain strong staff and facility capabilities at the national laboratories. A Facilities Modernization program for the Energy Research laboratories is essential if we are to continue to perform world-leading science. We cannot ask leading scientists to operate under substandard conditions - performing 1990's research in 1940's buildings. New building codes and new operating standards for cleanliness and chemicals use require that research be conducted in up-to-date facilities. The General Plant Projects funding provided by DOE is inadequate to meet standards for buildings, utility systems and roadways. The Multiprogram Energy Laboratories Facilities Support Program provides an initial framework for the Office of Energy Research to make inroads on the growing backlog of modernization needs. New scientific facilities and equipment are essential to moving the scientific enterprise forward, but so is providing basic, modern laboratory space.

Maintaining a first-rate scientific and engineering staff is uppermost in my mind as director of the Lawrence Berkeley Laboratory. That is why I am dismayed by the recent action of the House Appropriations Committee to eliminate the authority of laboratory directors to establish Exploratory Research and Development programs. This small but essential program has been used over the years to support innovative scientific ideas at their most exploratory stage. Research at this stage can often determine whether the idea is worthy of future DOE support.

This authority has also allowed laboratory directors to respond quickly to new scientific challenges and opportunities. A good example was the discovery two years ago of the new high temperature superconductors. The Department of Energy, without providing any new money, asked its national laboratories to accelerate work in this area. With the exploratory R&D programs in place, we were able to quickly respond and begin programs that will greatly contribute to our national effort in this field. Without this flexibility, endorsed by the 1983 White House Science Council review of the Federal laboratories, opportunities would have been lost. Our nation would have started this technological foot race with a significant handicap. I hope that this Committee can see the wisdom of giving the laboratory directors this flexibility, and will work with your colleagues to see this prohibition removed from the final Energy and Water Development appropriations bill.

Removing this handicap in the technological race still leaves a major stumbling block - the lack of support for technology research. Although the Congress is to be congratulated for establishing the Advanced Technology Program in the National Institute for Science and Technology, it is not enough. There are many other agencies, including the Department of Energy, with laboratories that could contribute to our nation's economic security. I recommend that the Department of Energy extend its view of technology transfer to include technology research in its National Laboratories that is founded on industry guidance and cooperation. As a complement, I recommend the establishment of a separate Office of Technology Research that provides specific funds to support such research.

Finally, our national economic strength demands mutual outreach between corporate America and the national laboratories. Even if national laboratories have the resources to develop the "missing link" of technology research, they will only have a significant impact if we can move the people with the knowledge of advanced technologies to industry. This may mean industrial scientists working in our laboratories and incentives to move national laboratory scientists into industry. Industry needs to provide guidance on the directions that the research should take. For this type of research, still far from marketplace competition, the earlier that industry is involved, the smoother the transfer of the fruits of technology researc.

I hope that my remarks today give some insight about how the Department of Energy national laboratories can benefit our country. They are a unique resource, and with the structural changes in our economy, more essential than ever before. With your continued support, national laboratories will be an important part of our national economic development program into the 21st century.

Senator BINGAMAN. Thank you very much. Dr. Wiley, you are our cleanup hitter. We are very pleased to have you.

STATEMENT OF DR. WILLIAM R. WILEY, DIRECTOR, PACIFIC NORTHWEST LABORATORY

Dr. WILEY. Mr. Chairman, I am pleased to be here. I will save some time, I hope. Instead of going through my prepared remarks, I think I will discuss with you the background of the Pacific Northwest Laboratory very quickly and use that as a basis for stating why we are capable of doing what we view our future to be.

First of all, we are the youngest of the national laboratories, having been in existence 25 years. In fact, Glenn Seaborg was helping us celebrate our 25th birthday a few weeks ago.

The idea here was diversification of the Hanford site at this time, that Battelle Memorial Institute, which is a public trust in the State of Ohio, a totally research and development organization—we do work for industry. The idea was to bring Battelle in and establish two integrated contracts. One was to use the government facilities and the Battelle facilities, which turn out to be a $55 million investment, as a government-industry partnership such that you would have the possibility of some vertical integration of basic science to technology deployment.

Twenty-five years later we have completed some 20 companies. Twenty-plus spinoff companies have come out of this, and we have evolved a history of contribution in the environmental area. The examples of this history of involvement in the environmental area are, for example, the vitrification plants which are used to solidify high level waste in the West Valley, New York plant or in Savannah River or now in Hanford. That technology came out of the laboratory through this vertically integrated process.

It seems as if basic fundamental high technology always goes down to real honest-to-goodness low technology when it comes to putting it to work.

Out of this, we have developed several other approaches to waste technology and waste treatment. This is a piece of obsidian glass [indicating] which is derived from the solidification of soil which contains hazardous materials and waste. We have also developed and the companies are marketing a slow release device which releases a herbicide. That herbicide permits the control of weeds. For example, we are in the business now of keeping weeds from growing between the cracks at O'Hare.

So with that brief background, where are we going? What are we, as one of the multi-program national laboratories, looking to do? We are looking to be involved as an institution without walls. I am calling it an institution without walls because I think what the Department needs if it is to make progress in technology transfer and education and in research and development is an openness which I in turn am calling an institution without walls.

This institution without walls will be comprised of many, many universities. We have established memoranda of understanding with universities all over the country, Montana, Idaho, Washington, Yale as well as the University of Kentucky. These unique universities interact with us on the very fundamental basic science end in a user facility we call the environmental molecular sciences laboratory. This laboratory conducts environmental research as well as basic fundamental molecular sciences. This is the end of the spectrum where the universities interact.

On the other end where technology transfer is to occur, we use this integrated contract that was signed by the government in 1965 to interact with industry such that we have some 1,000 industries with programs in the laboratory on an annual basis. The idea here is to devote the considerable resources of this national laboratory to environmental restoration, to global environmental change, to energy efficiency and to public health.

The idea of work we have done with the National Institutes of Health provides us with a mechanism for questioning whether we can make some progress in bettering the life of the elderly. So our health research will be kind of devoted to aging.

By opening up these national laboratories, we believe that the success of the national laboratories will continue, and we will be able to make contributions to the Nation both in technology transfer, energy research, in education and the better education of scientists and engineers.

With that, I will close, sir.

[The prepared statement of Dr. Wiley follows:]

Statement of
Dr. William R. Wiley
Director
Pacific Northwest Laboratory

Before the
Committee on Energy and Natural Resources
Subcommittee on Energy Research and Development

United States Senate
Washington, DC

July 25, 1990

INTRODUCTION

I appreciate the opportunity to discuss the programs and plans of the Pacific Northwest Laboratory, which is located at Richland, Washington, and managed by Battelle Memorial Institute for the Department of Energy.

The Department of Energy's laboratory system represents a unique national asset. The human and physical resources that comprise this system are truly unmatched by any other federal agency or private enterprise in the United States, or in any other part of the world. Moreover, scientific achievements emanating from these laboratories over the past 40 years have given rise to many major benefits and services, including new products and processes. In 1990, the U.S. faces a number of major new challenges in the areas of national security, energy security, and international competitiveness. And, just as in the past, the national laboratories must play an essential role in providing solutions to these challenges. The national laboratories must play an essential role in finding solutions to these challenges.

Each of the national laboratories has had its own particular process of evolution and record of accomplishment. While the Pacific Northwest Laboratory is the youngest of the laboratories--1990 represents our 25th anniversary--we can point with pride to our share of accomplishments.

BACKGROUND

In the mid-1960's, the Federal Government decided to segment the scope of work being conducted at the Hanford site in Washington. The research and development activities were defined as one scope of work and, out of that process, a proposal by Battelle Memorial Institute--a not-for-profit charitable trust--was selected to manage that function. Thus, Battelle "inherited" approximately 1400 employees and an annual budget of approximately $40 million in 1965, when the Pacific Northwest Laboratory was established.

The scope of work for the Pacific Northwest Laboratory (PNL) was at that time primarily one of supporting the nuclear materials production and nuclear reactor activities at the Hanford site, as well as associated health and environmental research programs. Over the ensuing 25 years, PNL has evolved into a multiprogram national laboratory with funding from virtually every programmatic office in the Department of Energy. And, like DOE's other national laboratories, PNL also performs research for other government agencies, such as DoD, NRC, NASA, NIH and EPA.

Unlike other laboratory contractors, however, Battelle has had, since its establishment, two integrated contracts with the Federal Government, one of which allows nongovernment-sponsored research to be performed by PNL scientists at our Richland laboratories. In 1989 alone, Battelle scientists and engineers at Richland conducted work for more than 150 clients from the private sector. Another unique characteristic of Battelle's contract with the Federal Government is the fact that research can be done in either the government-owned laboratories or the Battelle-owned laboratories at Richland. This is possible because when Battelle was awarded the contract to operate the Pacific Northwest Laboratory in 1965, it committed to develop a private contract research business as part of its diversification commitment to the region. Over the ensuing 25 years, this commitment has resulted in Battelle's investing more than $50 million of equipment and facilities in the State of Washington--at Richland, Seattle and Sequim. These facilities _and_ DOE's facilities are considered to be a "consolidated" laboratory. Research is performed under a "use permit" system so that scientists can conduct work for any sponsor in the most appropriate facility. The "consolidated" laboratory and "use permit" concepts have been the foundation of a very successful partnership for all parties, and have nurtured mechanisms for the transfer of technology from the public sector to the private sector. As a result, in 1990, Battelle's 3500 employees, representing a $300 million enterprise, serve at any one time more than 1000 individual clients from the public and private sectors.

PNL MISSIONS

Environmental Research

PNL's evolution over its first 25 years has been centered around health and environmental research and waste technology. Starting with the research role that was inherited when PNL was established, health and environmental research have always been a central part of the laboratory's mission. Consider these unique resources:

- PNL operates the only marine research laboratory in the DOE system. Part of Battelle's investment, this laboratory is located at Sequim, Washington on the Olympic Peninsula and is oriented toward water quality and the preservation and enhancement of marine life. In fact, several oil-spill bioremediation techniques have been developed at Sequim.
- PNL operates the only fully-instrumented research aircraft in the DOE system. Purchased with Battelle funds and equipped with DOE-funded instrumentation, this airplane has been used in many atmospheric chemistry studies relating to acid rain and other air quality questions. This resource will be very valuable in DOE's global environmental change programs.

- PNL has the largest health physics program in the DOE laboratory system. This capability has led to a greater understanding of the relationship between radiation and cancer through long-term health studies and the development of more sophisticated analytical detection instrumentation.

PNL scientists and engineers also have a long history of technology development for waste management. Consider these accomplishments:

- PNL developed the technology for vitrification of high-level nuclear wastes, including the process selected for the Savannah River, West Valley and Hanford vitrification plants.
- PNL engineers developed an in-situ vitrification process for immobilizing hazardous wastes, which precludes digging up, transporting, and storing these wastes at other sites.
- Geochemical and geohydrologic models developed by PNL scientists will aid the cleanup of subsurface wastes throughout the country.

This background, as well as the continued development of new ideas that come from 3500 scientists and engineers, has resulted in PNL being uniquely positioned to contribute to the solution of two major challenges facing the Department of Energy today--environmental restoration and global environmental change.

THE ENVIRONMENTAL AND MOLECULAR SCIENCES LABORATORY

Approximately three years ago, PNL began to plan for its flagship of the future. After careful review of other laboratory missions and our own technical programs, we initiated the process of acquiring the resources to create an Environmental and Molecular Sciences Laboratory (EMSL). This initiative is supported by research programs funded by the Basic Energy Sciences program and the Biological and Environmental Research programs in DOE. I might add that it is also envisioned that other DOE program offices, such as Environmental Restoration/Waste Management, Fossil Energy and Renewable Energy, will eventually be participants in the research programs within EMSL.

The United States is about to embark on an environmental restoration effort that dwarfs any scientific enterprise this country has ever launched--perhaps as big as the Manhattan Project itself. In fact, the current estimated cost for remediating DOE waste sites is equivalent to building a number of superconducting colliders or several space stations.

Many scientific problems related to environmental restoration and waste characterization are unresolved and enormously complex. Only through research and innovation can we reduce the cost, uncertainty and risk associated with such an undertaking. In broadest terms, the Molecular Science Center and a companion effort funded by the Biological and Environmental Research Program, the Environmental Sciences Research Center, will provide the resources that scientists at DOE sites around the country will need to understand the magnitude of the environmental problems we face, to identify cost-effective solutions, and to improve the understanding of natural systems so that we can develop innovative technologies. Basic research is needed to develop advanced sampling characterization and monitoring methods, performance assessment techniques, as well as improved methods for treating, isolating and containing contaminants where they are found (in situ). Research programs that will be supported in EMSL range from the molecular to the field scale, and include:

- A fundamental knowledge of natural systems to better predict contaminant movement and remediation in complex environments, including basic chemical and biological processes that control contaminant transport, transformation, and nature's ability to mitigate problems.
- Advanced sampling characterization and monitoring methods for determining the presence, and current and future behavior of contamination.
- Material interface issues that affect waste management, environmental restoration, and remediation technologies.
- New remediation concepts and technologies for inactive facilities, concentrate wastes, and contaminated environments, including advanced biosystems which use less energy and chemicals and take advantage of natural processes.
- Performance assessment methods to evaluate our ability to restore contaminated environments.
- Innovative new methods such as biomarkers to assess the environmental and health effects of innovative technology applications.
- Mitigating factors for health effects caused by exposure to toxic substances.

All of these gaps in knowledge and the ability to evaluate and demonstrate technologies in a field environment are being addressed as part of this environmental research program. The Pacific Northwest Laboratory has incorporated university faculty in these programs and will made its facilities and equipment available to the entire scientific community in addressing these important problems.

One of the unique components within EMSL will be a molecular science computing facility. Developing new knowledge and techniques for environmental restoration and waste management requires a detailed understanding of molecular processes. Such understanding will form the basis for improvements in our ability to predict contaminant behavior and movement in the environment and to develop innovative remedial measures for contaminated ecosystems. Computational molecular sciences will play a critical role in providing this knowledge. In order to meet the computational needs of the researchers, a molecular science computer facility is envisioned that will provide for the production computing needs of the research programs, and will provide access to a new computer architecture which shows significant promise for molecular calculations as well as visualization tools needed for efficient and effective analysis of molecular simulations. This facility and the associated molecular science software development effort have the potential to revolutionize both the performance of molecular calculations and the application of molecular simulations to real world phenomena. This resource could also be a node for the evolving High-Performance Computing Network, and this quest has been designated as one of DOE's Grand Challenges.

The Research Development Demonstration Testing and Evaluation Five-Year Plan just released by the Department of Energy has a section relating to Technology Development. However, many in the scientific community--through the National Energy Strategy hearings and other fora--have expressed their belief that the Department must allocate more resources for the basic and applied research supporting the development of new technologies in order for it to have any hope of reducing the costs, risks and uncertainties of cleanup. The Environmental and Molecular Sciences Laboratory represents the only concentrated effort in the DOE system--indeed the entire worldwide scientific community--that brings together in one location a multidisciplinary group of scientists and state-of-the-art equipment to address environmental restoration in a consolidated fashion.

The initial funding ($5.2 million for design) for EMSL is contained in the FY 1991 Budget currently before Congress. Limited funding for basic and applied research programs that will undergird this initiative is also included in the various program budgets, but increased investments would be most beneficial for accelerating the understanding of these complex issues. EMSL is expected to cost approximately $235 million and will be fully operational in 1995. It is intended to be a national user facility for the scientific community, with approximately half the scientists using the facility being visitors from academic and industrial laboratories from around the world.

GLOBAL ENVIRONMENTAL CHANGE

Another environmental challenge facing this country is global environmental change. The Department of Energy is a full participant in the governmentwide effort to develop a research program to determine if there is a serious environmental problem and what the research program should be to quantify the problems that are being identified. The Department of Energy has two initiatives that are a part of this program: The first is the Computer Hardware Advanced Mathematics and Model Physics (CHAMMP) Program. The objective of the CHAMMP Program in the near term is to achieve improved performance of existing climate system models by taking advantage of emerging parallel computers.

The second initiative is the Atmospheric Radiation Measurement (ARM) Program. The objective of the ARM Program is to provide an experimental test bed for evaluating the parameters of important atmospheric effects, particularly cloud and radiative processes, for use in atmospheric models. The ARM test bed will consist of a series of instruments at selected sites around the world. Each site will include a central facility with instrumentation for measuring radiation fields and local conditions such as surface and cloud properties, a three-dimensional mapping network of auxiliary stations surrounding the central facility with instrumentation designed to measure the three-dimensional structure of the atmosphere near the base site, and an extended observing network with instrumentation designed to collect the basic information and meteorological data needed to characterize the radiative transfer through the area of measurement.

Building upon the background that the Pacific Northwest Laboratory has had for many years in atmospheric chemistry, including the use of the Battelle aircraft to do cloud measurement studies and other activities in support of the National Acid Precipitation Assessment Program, PNL has been assigned the technical management role for the ARM program. A program plan has been developed and proposals received from a variety of research organizations and scientists from around the country. The combination of the research aircraft, as well as the Marine Research Laboratory and its experience in dealing with water quality and ocean research, provide PNL with two extremely unique capabilities for helping the Department implement this very important research rogram. The success of these programs are key to DOE having sufficient nowledge to formulate a credible National Energy Strategy.

NERGY SECURITY

While environment has always been the mainstay of our laboratory missions, "energy" has also traditionally been a very important part of our research portfolio. During the 1970's, the Department of Energy supported many new innovative ideas for concepts relating to energy production and energy conservation, and PNL participated in several of these research thrusts.

PNL's major response to the energy crisis has been focused around energy conservation activities. While there have been small programs in a variety of energy production technologies--solar, geothermal, nuclear, fossil, and energy storage systems--the largest concentration of activities by PNL has been focused on energy efficiency relating to buildings and industrial processes.

PNL manages four major energy efficiency programs for DOE. Efforts in the Buildings Program center on the development of Building Energy Standards and guidance for the energy-efficient design of commercial buildings. The building standards have been developed in cooperation with industry to facilitate acceptance by state and code organizations to provide near-term improvement in new building energy efficiency. The Advanced Energy Design and Operations Technology Program focuses on integrating expert knowledge embedded in artificial intelligence systems with computer-aided design (CAD) systems to enable architects and engineers to routinely include energy efficiency in commercial building design. Activities in the Federal Energy Management Program (FEMP) target the development of practices and procedures to facilitate the deployment of technologies, such as energy efficient lighting, in the federal sector to improve energy efficiency. Development and demonstration activities for Aquifer Thermal Energy Storage have shown that seasonal heating and cooling requirements can be provided at costs lower than conventional fuels.

PNL has also conducted the world's largest building sector end-use energy monitoring program for the Bonneville Power Administration. Information from this program has helped guide the Buildings and FEMP program activities and will contribute to the efforts focusing on utilities integrated resource planning.

A major element of PNL's energy efficiency programs is centered on technology deployment. The deployment thrust is to work in partnership with states, utilities, federal agencies and industry to provide for the transfer of technologies and knowledge to users. A model deployment process is undergoing development within the Pacific Northwest to use the utility system available within the Bonneville grid to demonstrate innovative technologies and practices that are yet untested in the commercial sector. Our belief is that active technology deployment is essential to improving our energy efficiency, and that this model process can be utilized by other areas of the country.

PNL's energy efficiency programs are also oriented towards the Industrial sector. For many years, PNL has been working with the aluminum industry to develop a more energy efficient aluminum production process. The cost of producing aluminum is primarily an energy consumption issue, as large quantities of electricity are required to produce final products in a variety of shapes, sizes, etc. PNL has been supporting a program that looks very promising in terms of developing a new inert electrode material in place of the materials currently used in the aluminum production process. Preliminary results indicate that approximately one-half of the cost of producing aluminum could be saved by the replacement of current electrodes with the new inert electrodes in aluminum production plants.

PNL has also been developing a program that is aimed at reducing industrial waste and energy consumption for small and medium-sized materials processing industries faced with environmental compliance requirements for continued operation of their facilities. As environmental regulations are promulgated, many materials processing facilities and industries are faced with changing equipment or process lines in order to comply with regulations. However, the economics of shutting down plants to incorporate new processes that have not been proven are not attractive for small and medium-sized industries. PNL has been working with these industries to develop a proof-of-concept facility that would allow them to evaluate and/or develop new processes with the objective of environmental compliance and energy efficiency when they are incorporated into their production operations. It is envisioned that this facility, to be developed over the next several years, will be a user resource for materials-processing industries throughout the country.

NATIONAL SECURITY

The national security mission of the Department of Energy also supports several programs at the Pacific Northwest Laboratory. While PNL is not a large player in this mission, we do have small programs that relate to verification technology and reactor design. Our current focus is on developing technologies for treaty verification and on supporting the Office of New Production Reactors in the design of the next generation of tritium-producing capability.

TECHNOLOGY TRANSFER

Technology transfer has always been a key component of the Pacific Northwest Laboratory mission. More than 20 companies have been "spun off" from technology developed by PNL during its first 25 years.

Let me give you two examples of technologies that have been commercially successful: As I mentioned earlier, the in-situ vitrification technology, or "ISV," was developed by PNL. In 1988, a company called Geosafe was created to commercialize the technology that underlies the ISV process. Geosafe was created with support from Battelle and is now a private business competing in the commercial sector for remediation of hazardous waste sites around the country. Another example is the commercialization of the biobarrier technology. The biobarrier concept is the controlled release of herbicides over an extended period of time by incorporating chemicals into a polymer, such as plastic, to create a slow release delivery system. The technology was originally conceived to solve a problem of root intrusion from surface vegetation into waste sites. Following successful demonstration at a DOE uranium mill tailing disposal facility, the concept was extended to problems facing the industrial sector. New products were developed from this concept which have led to application licenses for companies in the areas of geotextile fabrics, sewer gaskets and drip irrigation emitters. Other new products are currently being developed and tested for a variety of applications using this technology.

SCIENCE EDUCATION

Approximately two months ago, the Secretary of Energy released the results of the Berkeley Math Science Education Conference held in October 1989. PNL has for many years been supporting science education outreach programs with schools in the State of Washington. Our approach is based on working with schools to bring teachers to the laboratory for research experiences with our scientists and to take trained scientists to the schools. During this summer we have approximately 100 students and 75 high school teachers in the laboratory working with our scientists and engineers in a variety of ways to enhance teaching skills and motivate more students to be the scientists and engineers of the 21st Century.

Our approach is not just limited to precollege activities. The laboratory has been developing a strategy over the past several years to create what I have called a "laboratory without walls." This concept is based on utilizing the resources of the laboratory and the university community throughout the Pacific Northwest to create a consolidated set of resources that can be brought to bear on many scientific challenges facing us. Accordingly, we have developed institutional partnerships with all of the major research universities in Washington, Oregon, Idaho and Montana. We also have specific partnerships with other universities, including the University of Florida, the University of Kentucky, and Yale University. We have developed joint research proposals, faculty and scientists exchanges, and programs for faculty participation in laboratory research, so that we have the best talent that we can bring to bear on any of the programs assigned to PNL.

PNL also has an active partnership program with historically black colleges and universities and with schools with traditionally underrepresented groups in the science and engineering professions. We have memoranda of understanding with North Carolina A&T, Florida A&M, Alabama A&M, Southern University, and Prairie View A&M. We also are in the process of developing a partnership with an all-women's college--Saint Mary's College in South Bend, Indiana.

All recent reports dealing with the paucity of scientists and engineers indicate that more efforts must be made to bring minorities and women into the science and engineering professions. Women represent 50 percent of the population, but only provide 12 percent of the scientists and engineers in this country. Minorities currently represent slightly more than 20 percent of the population, but only 2 percent of the scientists and engineers. The student population in the United States is going to have a higher percentage of Blacks and Hispanics; thus, we must focus more programs now on those groups that will be part of an increasingly large percentage of our students, teachers, faculty, scientists and engineers in the 21st Century.

SUMMARY

Significant changes have occurred in the Pacific Northwest Laboratory's mission over its first 25 years, some of which were caused by external forces.

Let me cite some examples of how external forces have impacted Laboratory programs: In 1965, the United States was beginning a "build-up" for a war in Southeast Asia. In 1990, the United States is beginning the process of a "build-down" from the Cold War, and geopolitical relationships are proceeding in a direction never imagined, even as recently as one year ago.

In 1965, energy was plentiful in every form throughout the United States. Following two major oil interruptions--and various questions having been raised regarding other forms of energy--our energy supply situation in 1990 is perilous, with no apparent consensus on what is the best strategy for the United States to follow in the 21st Century.

In 1965, environmental issues were not a part of our national consciousness. CEQ, EPA, EIS, et cetera, were acronyms not yet envisioned. In 1990, the world arena is clearly worried about global environmental change in the form of polluted air, polluted water, and contaminated soil--with no easy solutions on hand for any of these challenges.

Even the neighborhood in which PNL exists has changed. In 1965, the Hanford Site was a major part of the government's nuclear materials production complex. In 1990, the mission has changed from nuclear materials to environmental restoration.

Out of these changes a major national laboratory has emerged. And, thanks to the many talented people at PNL, we are already making contributions to DOE's newest mission, environmental restoration. With the development of the Environmental and Molecular Sciences Laboratory and associated research programs, I believe PNL is in a position to make immense contributions, not only to DOE's environmental restoration mission, but to the advancement of the knowledge of the chemical sciences. With the support of this Committee and the Congress in general, this vision will become a reality and the world will be a better place to live for all of its inhabitants.

Senator **Bingaman**. Thank you very much. We appreciate the statement.

At this point I have been advised that Senator Domenici is on his way here from the floor where he had to make a statement. I think he had some questions for the previous panel, so we will dismiss this panel and let you folks go. We appreciate your statements very much.

I would ask the previous panel to come forward. I will ask them one question while we are waiting for Senator Domenici, and then I will have to leave. I think he is planning to complete his questions by 1 p.m. also, so I think this will be short.

Let me just ask any of you to comment, if you would, on the major obstacle that you see. Maybe this is too broad a question to get a very useful response, but let me ask it: Are there some institutional obstacles that Congress has put in the way of your laboratories adjusting and pursuing the important technology and science challenges that the country now faces?

Are there things that we need to do here in Congress, other than just shifting funds to facilitate your ability to be useful in meeting the technology and science challenges in the next decade or two?

Dr. **Narath**. I think the most important thing is to assure that we retain sufficient flexibility in the manner in which we invest at least some fraction of our funding so that we can direct our work towards what in our judgment are the most useful technologies.

Senator **Bingaman**. Dr. Hecker, do you have a view on that?

Dr. **Hecker**. I will certainly second that, and of course a lot of that is associated with this laboratory-directed R&D or institutional supporting research.

I guess the other comment I would make is to comment on Dr. Shank's concept of technology development. It appears to me it is not easy not only with the Department of Energy but within the government in general to do technology development in a useful way with private industry—that is, the Federal or national laboratories, be it ours or the energy-related labs.

You have taken some very important steps in that direction of adding technology transfer to the mission of the laboratories. I guess a suggestion that I would make, of course, is that along with that does have to come the support, but also it needs to be considered a part of the mission of the Department of Energy, not just its laboratories, so its programs are focused from the Department inside out to work the technology issue.

Senator **Bingaman**. Dr. Nuckolls, did you have a comment on that?

Dr. **Nuckolls**. I think you pretty well covered it. We had the same experience that Dr. Shank had with the x-ray lithography. That is, we were approached by AT&T some years ago, and we have expertise in x-ray optics as well as in solid state lasers that can produce the x-rays, and they offered to form a partnership to do it, but we needed to put up $5 million a year to do this, and we just did not have the flexibility to do it, and so the thing just sort of sat there, and I have watched the Japanese get serious and catch up. It is a crazy world, but something needs to be done.

Senator **Bingaman**. So the flexibility to react to needs that you identify is the main thrust, or a main thrust.

Dr. NARATH. There is another important aspect of this problem that I am not sure that the Congress can do anything about, but it strikes me that the development of commercially-useful technology cannot simply proceed through a science and technology push process. There has to be more understanding within the labs as to what is of real interest to industry. That is, what other market pull considerations to do that to achieve a greater understanding will require that the labs interact more strongly with industry.

One of the best ways to do that is to have lab personnel assigned to selected companies and have industrial people spend time at the national labs. I think we have the ability to make these arrangements today, but if I am mistaken, that is certainly one area where it would be useful.

Senator BINGAMAN. Let me defer to Senator Domenici and turn the hearing over to him at this point, since I do need to run. Thank you very much.

[Recess.]

Senator DOMENICI [presiding]. Might I say, Dr. Nuckolls, I have a question for you and then I am going to ask everybody a general question.

Without going into detail, one of the problems we have had up here that we have had, that you have heard us explain that we tried to fix in the appropriations bill with respect to flexible money—and we have. In the appropriations bill, we have reinstated 6 percent, as flexible money for the laboratories.

One of the reasons allegedly given in the United States House for taking away flexibility, and I think we could just as well talk about it, is that some members of the House perceive that an activity at Lawrence Livermore under their flexibility was one that a House Member did not like because it in some way was thought to be peculiarly the jurisdiction of NASA and was an interference with some significant R&D effort that NASA had. I did not say that I know that or that I believe that. I merely stated that happened to be a situation.

Now, I think it is important that we all know that even though this panel of Senators has been singing the praises of the national laboratories, be it the Oak Ridge or the Sandia National Laboratory, to put it in two categories, I think everyone should know that there is a lot of competition in terms of who ought to be doing what.

There is also some genuine concern that if permitted to be flexible some laboratories might take over the work or attempt to take over the work of a completed unrelated laboratory in some other aspect of the Federal Government's activities. Now, that is an issue.

Could you address that, not explaining that particular problem, but explain how you see that problem and what you think we ought to be doing about it up here?

Dr. NUCKOLLS. My first instinct, you know, in this case, was to withdraw from the activity, which I did when I found out about it in early May. I called up the Congressman. Staff had an objection to this and said we want you people to be happy and so we will not spend any of our DOE funds on this. It turned out there was a misunderstanding after that about whether it had really been done.

However, the thought occurred to me that there may be a better solution to this. It could be an example where congressional jurisdiction was not consistent with the national interest, and so I was puzzled, exactly, about that question that you asked.

I think the right thing to do in that case is to go back to the Secretary and let him and the head of the other agency in this case talk about it, or let the Congress and their staffs work it out, and meanwhile to stand on the sidelines. But I do not really have any better answer to the question. I would be interested in what my colleagues think.

Senator DOMENICI. Thank you very much.

Could I ask any of you or all of you this question? I mean, obviously every laboratory here in its evolution to this point in history has had some kind of principal mission and some kind of principal source of funding.

I believe it is fair to say that what is happening with changing economic times and changing needs that the strength of the laboratory with its original mission, or original couple of missions—that the strength is viewed by each of the directors and many of the personnel who are talented as leading them to do other things and feeling rather strongly that they can do other things rather well. Is that a fair assessment?

Dr. SHANK. Yes.

Dr. WILEY. Yes, Senator.

Dr. TRIVELPIECE. Yes.

Dr. HECKER. Yes.

Dr. NARATH. Yes, sir.

Dr. NUCKOLLS. Yes, Senator.

Senator DOMENICI. We want to see to it that in transition we make the best case for funding the national laboratories and their efforts. There are more than six, but let us just say the six that are here. And it seems to this Senator that in doing that we have to prove our worth. We have to prove the worth of what we are going to be doing.

And even though we want you to be independent, we want you to be vigorous and competitive and seek out where you have strengths, it seems to me that we have to find some way to assure the rest of the scientific community, and even members of Congress with other interests, that this is being done in an orderly, organized way with somebody, somewhere in charge, so that we do not get the kind of undesirable consequences that occurred in the example that I just gave.

Will any of you try your hand at some thoughts on how we ought to do that? Let us start with Al.

Dr. NARATH. Let me express a personal view. In the areas that we are discussing in terms of future growth, the reorientation, and so on, I do not think there is any room for—they do not exist—natural monopolies. I am a firm believer in the efficacy of a competitive approach. But there is fair competition, and then there is unfair or disruptive competition. I think it is very important that laboratories be given an opportunity to compete based on their established strengths. And then there needs to be a process whereby the results are evaluated and the program gradually, perhaps, shift in the direction of the laboratory that is producing the most.

I think the problem we have tended to run into is perhaps too much public marketing. You know it may well be that Lawrence Livermore had some outstanding and very innovative ideas in connection with the mission to Mars. The problem you get into is if these views are taken to the public too early in time. I mean there are ways to make views and opinions known within the responsible agencies and pursue marketing, if that is what you want to call it, at that level.

It is when you go outside that arena, and go public, that you run into difficulty. And speaking for Sandia, we simply would not permit that.

Senator DOMENICI. Al, do you have any thoughts?

Dr. TRIVELPIECE. I wanted to pick up on this, but start back slightly. The Department of Energy, if you look at its organic act, allows for payment of IR&D funds, much as the Department of Defense does. And what that means is that companies that do business with the Department of Defense can allow for three-quarters of a point of their GNA or something like that to go to IR&D, as long as it, in the case of DOD, meets certain tests, one of which is potential military relevance.

The Department of Energy also pays such amounts for its contractors. So a for-profit contractor not associated with the laboratories, a General Electric, Westinghouse, or any of these companies, would receive monies from the Department of Energy to do internal research and development that would renew their capabilities in new areas, permit them to do things they had not previously done, and to begin to move out of things that they were no longer effective in competing in.

I noticed that there was an asymmetry in the sense that at least the non-weapons laboratories has no such formal program in DOE. And one of the things I did during the time I was Director of Energy Research was I had a hand in causing this exploratory fund order to come into being. And one of the principal arguments was that the Department of Energy should pay as much attention to the health, well being and renewal of its own facilities as it does of the for-profit corporations, such as Westinghouse and others, through the IR&D process.

So this was simply an attempt to try to level the playing field between the circumstances that private industry enjoyed in getting funds from DOE and what the laboratories receive. There was still some asymmetry between the weapons labs and the non-weapons labs. I think the recent concern over this may well in fact level the playing field. And I agree with Al Narath, that is the issue: we would like to have the flexibility to take advantage of these opportunities as we see them, but to do so under circumstances in which it is a fair, objective, and level playing field.

And I think that the natural competition may in fact drive things in that direction. Because no scientist wants to be involved in an activity in which he is the second person in the program to present a paper. There is no particular reward for publishing the second paper to discover an effect. That natural selection process probably prevents the kind of duplication which, when people look at large programs and see names that look moderately similar, are concerned might be occurring.

I think the natural competition tends to do it. But it should be on a level playing field. We need to have a level playing field among us. And as the activities at the weapons labs and the weapons area may be ramping down, some of us in the non-weapons laboratories are perhaps a bit fearful that that will give them an unfair competitive advantage in areas where we should be competitive.

Now I do not know how all this sorts itself out, but I think that is one of the concerns that is laying on the table among us.

Senator DOMENICI. Does anybody else want to comment on that one?

[No response.]

Senator DOMENICI. We are only going to have about 10 more minutes, so I am not going to keep you too long.

Let me ask Dr. Hecker a specific question, and then if it has some generic application, perhaps some of you could comment.

Dr. Hecker, within the past year, a couple of your scientists met at length with the Lovelace Foundation of Albuquerque, NM, regarding a possible research project in the medical field. And it was very interesting. I attended one of the meetings and then was briefed. The use of laser technology in a non-invasive way to address current liver ailments which, if it would have worked, would have been dramatic in terms of current therapy.

It got down to the point where a consortium was about to be formed, and the conclusion, as I understood it, was that you were not able to complete it because if you looked at the scope of the project, it did not fit within any mission and/or charge that Los Alamos had.

I did not ask the Secretary about that, but as you note, he constantly refers to the energy policy that he is developing has disclosed technological deficiencies in the country. I have difficulty understanding that. I think that technological deficiencies are not related to energy. They may be related to America's economic future. But in some way we seem to have to tie back the activities to a rather stringent definition of what your lab, just speaking to you, are supposed to be doing for the country.

Is this a problem for you? And if it is a problem for you, is it also a problem for the others? And what should we do about it?

Dr. HECKER. It is a problem we discussed earlier. In fact, Dr. Shank also mentioned it, this problem of taking a technology and then doing some good with it. In this particular case it was a medical application of lasers. It was based on the fact that there has been this enormous investment at Los Alamos as well as at some other DOE facilities.

So the question was, first of all, is there a push from the technologies, and yes, we have to push because we have the lasers and an interest in medicine. Is there a pull or a need? The answer was yes. We work very closely with the Lovelace Foundation, with the medical school at the University of New Mexico. There was clearly a need.

Senator DOMENICI. And they had some other users beyond that.

Dr. HECKER. Absolutely, but the problem was it did not fit into any of the government boxes for developing that technology, and so it is one of the issues that in spite of the fact that we have a technology transformation, these efforts do not necessarily fit anyplace within the Department of Energy in order to develop them.

Senator **Domenici**. Dr. Shank.

Dr. **Shank**. One of the things that I have realized after coming to Lawrence Berkeley in September after 20 years at AT&T Bell Laboratories, is that I see a number of unique resources that exist only in the Department of Energy. We are building an advanced light source that will be unique in the Nation. It will not be built anywhere else.

We have a very narrow mission in the Department of Energy that as you described, if the Nation is going to get the real value out of this investment, I think we have to have a chance to take and use those resources in the broadest way we can, and in ways that will allow us to do the technology research that will allow the Nation to really get the value out of that investment that has been made. And I see that as an impediment and it was a surprise to me, coming from industry, to see all this valuable equipment and knowledge not being able to use to enhance our competitive advantage worldwide.

Senator **Domenici**. Al, do you have a comment on that?

Dr. **Trivelpiece**. The test quite frequently is one which has to do with turf. I always think that the test should be one that has to do with excellence. Either the work is excellent or it is not. If it is not excellent, the Department of Energy should not be doing it. If it is excellent, perhaps this issue of whether or not it falls within the specific narrow range of a mission statement ought to be, if not overlooked, at least tactfully ignored.

Dr. **Wiley**. Senator, I think to a large extent, it is ignored in some sense. We have the Stevenson-Wydler Act which permits us to do certain of these things with industry. For example, I was listening to the liver problem. We have a need to tag antibodies to take radioactive materials to tumors and to irradiate that.

Now, having the health physicists who are capable of doing that, we have simply utilized, perhaps, a spread of the scope to make that happen, but we made it happen. So, I think that there is sufficient latitude in most of the multi-program laboratories to do these things.

Dr. **Narath**. I think the key ought to be the value to the Nation. I think it takes more than excellence. There needs to be some judgment as to whether there is a real payoff. In our case, we have been able to finesse the problem. As you know, we have worked on insulin delivery systems and some related medical applications. In every case, we have been able to argue successfully that there was some reverse benefit that flows to the laboratory which would impact the weapon program.

No one has ever examined that argument too closely, but I would be very unhappy if the day ever came where what I consider to be an important economic application were denied because somehow the application was not within the mission statement of the laboratory.

Senator **Domenici**. Let me just do two things. I wonder if the three laboratories that are the—Los Alamos, Sandia and Livermore would answer this question for the record. Since Senator Ford has asked about patents, I wonder if you would answer for us whether the National Competitiveness in Technology Transfer Act is working with reference to patents, proprietary interests, exclusive agreements so that proprietary information is kept secret for a reasonable period of time. And to the extent that it is not, if you have any suggestions about further improvement, I would like you to give us those. Incidentally, Dr. Hecker, we have come a long way from those first meetings 5 years ago in Albuquerque to where we are today, and I think it took us a long time. But you would agree we have made some pretty big giant steps?

Dr. HECKER. Absolutely. And the direct answer to your question is that the legislation, I think, provides all of the important tools to take care of those issues. I think the crux of the matter right now is, is DOE working from either a regulation or a contract change standpoint to put those terms into effect, and that is still on its way through the system. And so therefore, it is not in place yet.

Senator DOMENICI. I wonder if the other three labs would like to answer that question. I do not want to burden you with it if Stevenson-Wilder and the other things are working absolutely perfectly. Al, do you think you would like to give us a little try at that?

Dr. TRIVELPIECE. I would like to add some additional information for the record on that subject.

Senator DOMENICI. I understand that in the past I have blamed part of it on DOE's patent lawyers and the like, and I do not want to put you all on the spot, especially since the secretary is working so well in this area as compared to others. I would have invited you to do it 3 years ago in red and underlined it, but I understand you are going to be judicious about wherein the blame lies if it is not going quite well. Is that right? Okay. I know you are.

Well, my last question, the staff is telling me we are going to vote here soon and they are going to have another hearing. They want me to close up. But I want to ask you a question. I know we are going to go through a lot of things before we actually get this situation in a stable position. We may have great ideas on how we are going to manage this whole transition, and frankly, the way Congress has split up the jurisdiction, we may just walk our way through the quicksand.

But in any event, I think if we are talking about technology transfer, we are talking about scientific breakthroughs, and if we are talking about enabling technology, and if we are talking about improving the education of our young people, and making some strides in environmental restoration technology, let me tell you, my own view is that we are going to have to prove ourselves rather regularly. I cannot tell you how strongly I feel that we did not have to do that when we were the sole source of defending the free world from nuclear bombs and the nuclear breakthroughs because no one wanted the challenge. And when we ask for $500 million a year for each of the laboratories, they said, is that enough, and you did the work great.

But I am interested in some basic thoughts on how we are going to score our successes and I just threw out the report card notion with the Secretary. I have no idea whether it will work, but I have, for those whose labs I have not visited.

I had a chance to visit Sandia recently—and certainly I visited Los Alamos many times—but on the recent visit for every presentation made by Sandia on a technology there was an effort made to, in an objective manner, talk about where it ended up and what it meant where it ended up, so that if a breakthrough occurred it ended up as part of something in the defense establishment as an applied technology. And I suggested, and they did it, put a value on that, as one might do if you were talking about the private sector. If you had a breakthrough, and a patent went, and a technology transferred, and $5 billion worth of VCRs were produced, one would say the technology was transferred.

It is not all that clear a report card, but I am genuinely interested, not only for the Secretary, who might want to do this, but I think from our standpoint that we might try to help encourage some objective evaluation that we can use in oversight to ultimately say, we are justified in doing this at Los Alamos, that this, and this, and this happened, and it has a value to society of such and such.

Dr. TRIVELPIECE. I go regularly to the Industrial Research Institutes meetings. They had a speaker at one of the last meetings who looked out over us and said, "You are a variable overhead expense," and he repeated it about three times. What that means is that, in the oak paneled room circles, that when you are starting to look for places to cut, research is the first place that gets cut, and quite frequently that can occur on the basis of a very objective test. And so I worry a little bit about trying to get what appears to be an objective test that could have a conclusion built into it before you even ask the question seriously.

So we need to also realize that there is a balance that is needed—not just the next quarter's earnings need to be looked at, but in fact, the health of the Nation over a 15- or 20-year period, in which basic research plays an integral element.

Senator DOMENICI. I agree.

Dr. SHANK. I have a concern about a test which is too narrow, much like Al's. I would just like to inject an experience of my own. When I was at Bell Laboratories we wanted to learn about x-ray optics. The place where the knowledge base for that was in Livermore and at LBL. There was considerable exchange of information that went to AT&T. That was never listed in any book as a valuable effort, and so in some kind of a score mechanism, you would get a zero, but the value to the Nation of having that knowledge base there is extraordinary, and any evaluation process should attempt to put some value on that as well.

Dr. HECKER. The way I see it, the bottom line is we have got to help U.S. industry and they will have to vote with their feet, and that is, they will have to come to our places, share those research facilities, and share in the collaborations. If we succeed in that we will have succeeded in the process of tech-transfer.

Dr. NARATH. I agree.

Senator DOMENICI. You understand, if I knew how to do an evaluation of something as significant yet as complex as this, I would introduce a statute saying, that is how we are going to judge you. I do not, but clearly we are going to be confronted with this regularly, and my passing shot at you and remark is, please, on some of this exotic research that is so meaningful yet so difficult to understand because things are moving so fast, that you have to try your best to make it understood. I mean, it is nice to call a press conference and say you are doing something, but it is awesome to watch the media and then read the story, and they have no idea what material processing center for something or other is. So, you are so ingenious, you may have some way to figure out some new models or something so we will be able to brag on you a little more.

I think we are going to go in recess and they are going to meet on something else at 1:30. Thank you very much.

[Whereupon, at 1:20 p.m., the hearing was adjourned.]

APPENDIX

Additional Material Submitted for the Record

Statement by the
American College of Nuclear Physicians
and the
Society of Nuclear Medicine

THE FUTURE OF NUCLEAR MEDICINE AND THE DOE NATIONAL LABS

July 25, 1990

The future of the Department of Energy National Laboratories is promising, but not imminent. As a nation, America once lead the world in science and technology. Unfortunately, due to budget constraints, heavy regulation and a shift to a service oriented economy, we are no longer in such a position. In no other high tech industry is this better illustrated than in Nuclear Medicine.

The American College of Nuclear Physicians and the Society of Nuclear Medicine represent over 12,000 Nuclear Medicine physicians, scientists and technologists. It is a medical specialty which uses radioactive materials (radioisotopes) in the form of radiopharmaceuticals to diagnose and treat diseases ranging from cancer to hyper-thyroidism. More than ten million patient procedures are performed on the American public every year. Other industries are also reliant on radioisotopes to study the effects of new drugs or pollutants in a living system. Not only medicine, but the food, pharmaceutical, and farming industries have a vested interest in the future availability of radioisotopes.

Several sections of the Atomic Energy Act acknowledge the Government's obligation to provide nuclear byproduct material for "Medical Therapy and Research and Development" (42 U.S.C. sec. 2134). The Department of Energy has sporadically produced such products for medical use in the past. All DOE operated reactors and accelerators have given the medical community a low priority. This conflict of priorities has become particularly apparent in recent years. In fact, it is not unlikely that a physics research project could monopolize one of the two DOE facilities which produce medical isotopes, for three years.

Recently, Nuclear Medicine has experienced a marked decline in the availability of materials particularly for research, but also for clinical use. Although the United States continues to maintain a dominance in the utility and development of radioisotopes in science, health and industry, it lacks the commercial ability to produce radioisotopes on a continuous basis -- year round or daily -- and we are forced to rely on foreign suppliers to provide the radiotracers.

Only two national irradiation facilities produce a nominal amount of byproduct material for nuclear medicine; the Brookhaven Linac Isotope Production Facility (BLIP) and the Isotope Production Facility (IPF) at the Los Alamos Meson Physics Facility (LAMPF). Both machines were designed for physics experiments and are controlled by these operations. As stated in the proceedings of the DOE workshop on The Role of High-Current Accelerator in the Future of Nuclear Medicine, "The radioisotope production programs at BLIP and LAMPF are approaching subcritical levels. How much longer can these national resources operate effectively without a commitment to the future?"

We suggest that we wait no longer and that a study on the feasibility and cost assessment of a dedicated accelerator for the production of medical isotopes be conducted immediately and should be completed by early 1991 for Congressional consideration in the FY92 budget.

The SNM and ACNP have decided to make this issue a priority. Our goals are to counter dependency on foreign suppliers, rejuvenate a fledgling U.S. radiopharmaceutical industry, maintain and vitalize research, and provide a field for educating radiochemists and physicists. Discussions have already been initiated with several Members of Congress in an effort to begin working toward a **National Biomedical Tracer Facility (NBTF)**, as it has been called.

Peer-reviewed reports on the necessity for an NBTF were published by the Subcommittee of the Health and Environmental Research Advisory Committee (HERAC) from the Office of Energy Research, U.S. Department of Energy in the August 1989 report on Nuclear Medicine, and in the Los Alamos report on The Role of a High-Current Accelerator in the Future of Nuclear Medicine in May 1989. The abstract from the Los Alamos report is attached for reference.

The NBTF would have three main objectives; Education, Research, and Production. Issues surrounding research and production needs are described in detail in the Los Alamos and HERAC reports, however, education is a concept not fully explored previously.

The education of persons to study and work in these fields that utilize radioisotopes is very limited in the United States. In a period of three years, Nuclear Medicine technology schools decreased in numbers from 141 to 106, with current programs operating at only 63% capacity. However, according to the June 1989 Institute of Medicine study, the need for specialists will increase by 23% by the year 2000. This only compounds the current manpower shortage crisis. The demand for doctoral radiochemists, radiopharmacists, nuclear engineers, and Nuclear Medicine scientists is very high. On average, twelve Ph.D. level radiochemists are graduated each year in the U.S., yet there is an estimated teaching, research and industrial need of greater than 400 radiochemists per annum. The NBTF would undoubtably serve as a national education and specialty center for nuclear specialists.

The ACNP and SNM ask that the Congress direct DOE to conduct the aforementioned feasibility study in the FY91 budget. For the preservation of nuclear technology and research advancement, this is a critical and timely commitment. We urge the Members of the Subcommittee to support the establishment of an NBTF in one of the DOE National Laboratories.

PROCEEDINGS OF THE DOE WORKSHOP ON THE ROLE OF A HIGH-CURRENT ACCELERATOR IN THE FUTURE OF NUCLEAR MEDICINE

Compiled by

David C. Moody and Eugene J. Peterson

ABSTRACT

The DOE Workshop on the Role of a High-Current Accelerator in the Future of Nuclear Medicine was held at Los Alamos National Laboratory August 16-17, 1988. The meeting was prompted by recent problems with isotope availability from DOE accelerator facilities; these difficulties have resulted from conflicting priorities between physics experiments and isotope production activities. The workshop was designed to be a forum in which the nuclear medicine community, isotope producers, industry, and other interested groups could discuss issues associated with isotope availability (including continuous supply options), the role of DOE and industry in isotope production, and the importance of research isotopes to the future of nuclear medicine. The workshop participants endorsed DOE's presence in supplying radioisotopes for research purposes and made four recommendations:

(1) **DOE should immediately provide additional support for radionuclide production in the form of personnel and supplies.**

(2) **DOE should establish a policy that would allow income from sales of future "routine" radionuclide production to be used to support technicians. Instead of production being subsidized, users would be charged directly for the materials they use.**

(3) **DOE should obtain a 70-MeV, 500-μA variable-energy proton accelerator as soon as possible. It should appoint a committee(s) for siting and machine selection. Once the facility is operating, BLIP and LAMPF should be used for radionuclide production that requires higher energy particles.**

(4) **DOE should also immediately solicit proposals to evaluate the usefulness of a new or upgraded high-energy, high-current machine for production of research radionuclides.**

This proceedings volume is a summary of workshop sessions that explored the future radionuclide needs of the nuclear medicine community and discussed the DOE production capabilities that would be required to meet these needs. Four position papers defined radionuclide production and the needs of the nuclear medicine community; the following discussion sessions focused on problems associated with isoitope availability; and the above recommendations were unanimously adopted.

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Statement of the

Inter-Council Committee on Federal Research and Development

of the

American Society of Mechanical Engineers

on the Role of the National Laboratories in

Engineering Research and Engineering Education

Submitted for the Record

to the

Senate Subcommittee on Energy Research and Development

of the

Committee on Energy and Natural Resources

August 10, 1990

Mr. Chairman and Members of the Subcommittee:

The Inter-Council Task Force on Research and Development of the American Society of Mechanical Engineers (ASME), is pleased to present this statement on the role of the national laboratories in engineering education. ASME is a non-profit technical and educational organization with 119,000 members, including 22,000 student members. These comments represent the views of the Inter-Council Task Force, rather than a position of ASME.

The national laboratories of the U.S. government have made numerous significant technical contributions to this country and to the world. They have, and still do, employ many of the best technical minds in the world as staff members. There is little doubt that these institutions should be maintained at support levels which will permit them to continue functioning as effectively as possible during this time when our national needs are changing. We support the maintenance of the laboratories and consider the facilities and technical staffs to be valuable national resources.

While our interests pervade the broad spectrum of activities of the laboratories we wish, at this time, to focus on their role in support of our universities - particularly regarding advanced education and research.

The national laboratories have a long history of collaboration with our research and teaching universities. Many engineering and science graduate students have done part - in some cases all - of their dissertation research at the laboratories; this practice continues. The experimental resources of the laboratories are generally excellent, and they possess capabilities that are in many cases unmatched in the world. As our national goals are changing and, concurrently, our needs for technically-trained people change, the laboratories have unique opportunities to be involved in the new educational restoration, transportation, depletion of readily-available petroleum reserves, international competitiveness, and the like. The solutions to these problems will certainly involve technology that is unknown today, and these solutions will likely be achieved by young people who are yet to engage in postgraduate education and research. The optimal use of these people resources dictates that we maintain the best research capabilities possible. It is our feeling that the national laboratories offer such potential.

This educationally-related role is not a new one for the national laboratories, as we have already noted. In the future this linkage between the laboratories and universities should be strengthened and expanded. Many engineers and scientists receive some of their education at smaller non-research oriented universities and colleges. Even though the research component of these educational institutions is not great the laboratories may still play a role in the teaching function. Summer employment for undergraduate students at laboratory sites can be a powerful motivation for continued education. Faculty members from these institutions can also profit from summer or sabbatical leave opportunities, whereby their exposure to state-of-the-art facilities and concepts will enhance the subsequent education of their students. Conversely, national laboratory-sponsored sabbaticals for laboratory staff at universities would have comparable benefits for the national laboratory staff and the university research programs as well.

We suggest that programs be funded at enhanced levels to provide collaborative research opportunities between university researchers and the national laboratories. It is our opinion that certain programs should be established specifically for this kind of cooperative education and that such programs should include university faculty members as equal partners in the research. The federal agencies involved: the Department of Energy, Department of Defense, the National Aeronautics and Space Administration, should all include programs specifically earmarked for university-laboratory collaboration.

We conclude this testimony with a concern. In all of the discussion presented thus far we have repeatedly mentioned the collaborative nature of these educationally-related programs. There is some indication that certain laboratories may be developing educational facilities and programs which will make them pseudo-universities, and thus put them in competition with established institutions of higher education. This sort of development is not viewed as healthy or appropriate. Each type of institution should do what it does best. The national laboratories represent a potential resource of major proportion as partners with our universities in the area of technical education. We are confident that much good will result from the synergism between these institutions.

Thank you for the opportunity to express these views.

STATEMENT OF

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FOR

HEARING ON THE CURRENT OPERATIONS AND FUTURE MISSION OF THE DEPARTMENT OF ENERGY'S NATIONAL LABORATORIES

PRESENTED TO

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES

JULY 25, 1990

STATEMENT OF

GLENN VANSELOW
EXECUTIVE DIRECTOR
PACIFIC NORTHWEST WATERWAYS ASSOCIATION

The Pacific Northwest Waterways Association (PNWA) is a regional association that has been working for 56 years to increase the economic vitality of the Northwest. We work to develop and maintain the Northwest region's natural resources, maintain an adequate supply of energy, and promote trade and transportation in the region.

PNWA membership includes 112 organizations and individuals in Oregon, Washington, Idaho, and Northern California. PNWA represents:

- Public port authorities on the Pacific Coast, Puget Sound, and Columbia/Snake River System;
- Public utility districts, investor owned utilities, and the direct service industries of the Bonneville Power Administration;
- Irrigation districts;
- Grain growers, grain grower cooperatives, and upriver elevator companies; and
- Transportation providers, consulting engineers, and other economic development interests.

The Pacific Northwest Waterways Association is pleased to present its comments on the Department of Energy's national laboratories. PNWA has long supported the Idaho National Engineering Laboratory (INEL) and the many research activites at the Hanford Reservation.

I wish to emphasize our organization's continued support for Department of Energy activities at both facilities. Both facilities provide special capabilities that cannot be replaced elsewhere. INEL and the Fast Flux Test Facility at Hanford INEL are the premier research and development facilities in the Northwest and the nation. Without these laboratories, the United States will lose its world-wide competitive edge in nuclear engineering, technology transfer, medical research, biotechnology, and more.

The economic impact of these facilities is important to the region. The salaries, contracts, and capital improvements contribute billions of direct and indirect dollars to the economies of Idaho, Washington, and the Northwest. But even more important than the earning power, is the brainpower that these two facilities bring to our region. Hanford and INEL attract highly educated, creative, motivated employees and contractors. They, in turn, create thriving communities where intellectual capital is invested and multiplies as it ripples through our people and our educational and social institutions in the same way dollars multiply as they ripple through the economy.

The research facilities at Hanford and INEL are valued institutions in this region and in this country. PNWA strongly supports both facilities and urges their continued operation.

The Pacific Northwest Waterways Association appreciates this opportunity to present our comments to the Committee. Thank you.

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